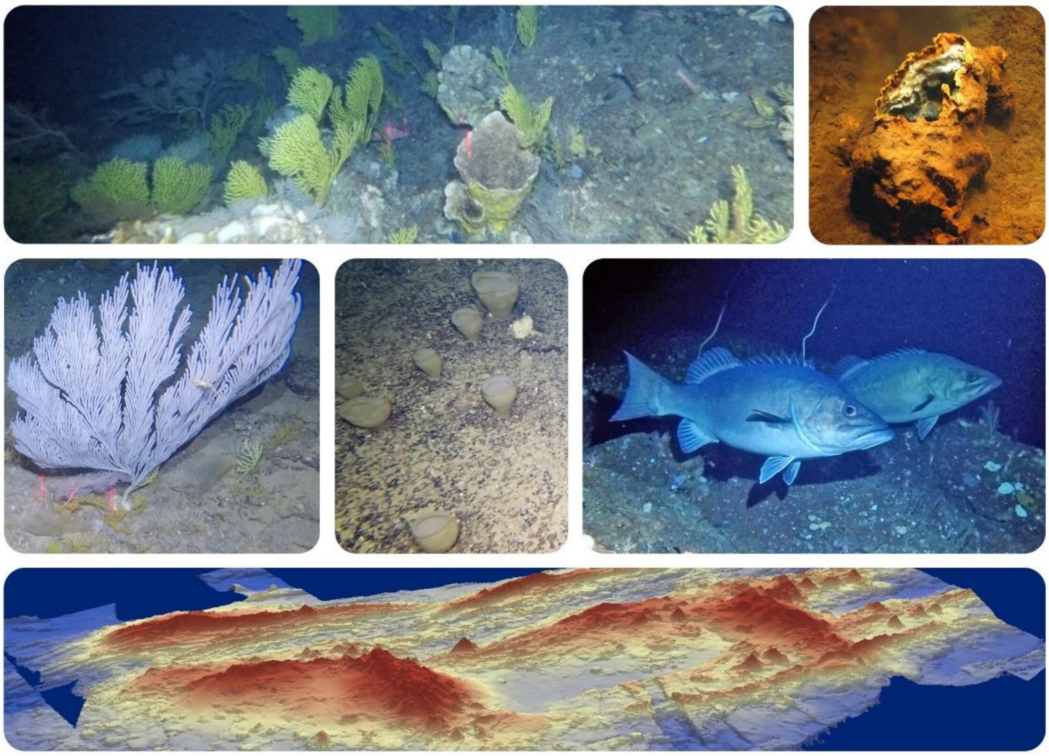

Systematic conservation planning scenarios for the Azores deep-sea

Final scientific report
July 2020

Part 1 – Executive summary

Telmo Morato[1,2], Magali Combes[1,2], Joana Brito[1,2], Luís Rodrigues[1,2], Carlos Dominguez-Carrió[1,2], Gerald H. Taranto[1,2], Laurence Fauconnet[1,2], Manuela Ramos[1,2], Jordi Blasco-Ferre[1,2], Cristina Gutiérrez-Zárate[1,2], Christopher K. Pham[1,2], Ana Colaço[1,2], José M. Gonzalez-Irusta[1], Eva Giacomello[1,2], Marina Carreiro-Silva[1,2]

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16 Julho 2020

Executive summary

In order to comply with the provisions of the cooperation protocol between IMAR and the Blue Ocean Foundation, namely in which concerns with the Clause Six, (f) *submission to the final Blue Ocean Foundation of Report on the Blue Paper*, and the Description of Work of the European Union's Horizon 2020 research and innovation programme, under grant agreement No 678760 ATLAS WP6, and the PO2020 MapGes project, Mapping deep-sea biodiversity and "Good Environmental Status" in the Azores: assisting with the implementation of EU Marine Strategy Framework Directive (Acores-01-0145-FEDER-000056).

The Azores Marine Ecosystem

The rich seafloor topography of the Azores comprises island slopes, seamounts, deep fracture zones, trenches, a considerable extension of the Mid-Atlantic Ridge (MAR) and abyssal plains. This diversity of habitats supports diverse ecosystems including hydrothermal vents, cold-water coral reefs and gardens and sponge aggregations. Over the last decades, extensive scientific research supported by multiple projects has permitted a better understanding of the ecological importance of deep-sea ecosystems in the Azores and the threats to these ecosystems. New deep-sea species, biotopes and even hydrothermal vent fields have been discovered, affirming the Azores as a hotspot of biodiversity, notably with the highest number of cold-water octocoral species in the North Atlantic.

The management and conservation challenge

In the Azores, as elsewhere, anthropogenic pressures are affecting the state of pelagic and benthic habitats and species. For example, there is "an increased perception" that fisheries stocks have been decreasing over the last decade, probably due to over-exploitation. Also, benthic ecosystems such as coral gardens have experienced reductions in their structural complexity caused by the removal of large arborescent corals during longline fishing, with consequent loss of associated biodiversity and the ecosystem services they provide. Emerging threats associated with deep-sea mining and climate change may impose additional pressures on local ecosystems, with experimental and modelling studies showing impacts on the health and survival of sensitive species such as corals and demersal fishes. Several areas of the Azores may fit the FAO criteria for defining Vulnerable Marine Ecosystems (VME) while others may be considered priority habitats in need of protection by the OSPAR Convention for the protection and conservation of the North-East Atlantic.

Existing management and conservation efforts

The current fishery resource management strategy of the Azores is based on the EU Common Fishery Policy, implemented primarily through total allowable catches (TACs) for various species and including prohibited species such as some deep-water sharks and the orange roughy. Apart from fish quotas, the Regional Government of the Azores has implemented several technical and spatial measures including: an extensive area where bottom-trawling is banned; move-on rule; seasonal fishing closures for blackspot seabream;

prohibition of longlining within 6nm from the islands shores. Moreover, the Azores Network of Marine Protected Areas has the overall objective to protect and restore biodiversity and habitats, particularly in the deep sea, that have been negatively affected by human activities, or might be negatively affected in the future. The Azores Network of Marine Protected Areas includes the different Islands Natural Parks within the territorial waters (12nm) and the Azores Marine Park beyond territorial waters. The Azores Marine Park is composed of 16 Marine Protected Areas, covering an area of 135,507 km both within and partially beyond the Portuguese EEZ. Various seamounts and hydrothermal vents are also listed under international network of MPAs such Natura 2000 and OSPAR.

The Condor seamount leveraged spatial conservation

The Condor seamount was designated as a temporary closed area in June 2010 after a collaborative, bottom-up process involving scientists, local fishermen, tourist operators and the Regional Government of the Azores. This closed area has been monitored ever since and the signs of fish stocks recovery has helped demonstrating to all stakeholders the potential effect of fisheries closed areas, and most importantly, facilitated the adoption of similar approaches in other areas within the Azores EEZ. More recently, the fisheries sector along with the Regional Government of the Azores demonstrated interest in implementing some fisheries closures in Mar da Prata with the main objective of rebuilding commercially important fish stocks in this perceived overfished area. More recently, the Regional Government of the Azores, the Oceano Azul Foundation, and the Waitt Institute signed a memorandum of understanding over the "Blue Azores" Program, focused on promoting the conservation and sustainable use of resources, by declaring 15% of the Exclusive Economic Zone of the Azores as new marine protected areas.

Systematic conservation planning for the deep-waters of the Azores

The implementation of such network of closed areas may have very different short-, medium- and long-term outcomes depending on the extent (size), design (shape), and location (placement and spacing) of closures. Therefore, explicit, objective-based and quantitative approaches, such those used in systematic conservation planning (SCP), can inform the selection of priority areas for conservation to achieve specific management goals and objectives. Here, we used SCP techniques to develop multiple fisheries closures scenarios to inform the selection of priority areas with the overarching management goal of:

> *"Protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores EEZ in a changing planet, while allowing the environmental sustainable use of natural resources for current and future generations."*

The SCP approach used here, is based on a multiple step framework can be summarized as follow:

1- Identify a set of ***management and conservation goals and objectives*** along with guiding principles and design criteria that determined the nature and characteristics of the scenarios;

2- Define the ***spatial planning area*** to be considered in the systematic conservation planning. Based on the "science-based" principle, the spatial planning area was divided into "data-rich" and "data-poor abyssal" spatial planning areas;

3- Identify the ***Important Areas*** that based on current best available knowledge (data-driven approach) are features of particular ecologically or biologically importance and the most suitable to achieve the planning goals. These areas should always be included in the scenarios' solutions;

4- Identify the ***Important Resources*** that are defined as those species, habitats or functions considered most suitable to achieve the management and conservation goals. A prioritization approach is used to complement the Important Areas with areas that based on current best available knowledge (data-driven approach) contain important resources;

5- ***Compile the best available data*** on biological and environmental conditions, as well as human uses, in the planning area. A particular focus should be given to collect information that would specifically address the agreed management goals and objectives. Also extremely important, is to ***identify the main knowledge gaps*** and to develop active efforts to fill those gaps;

6- Identify how ***existing humans uses*** should be considered in the prioritization approach (the cost model) and that could target areas with high conservation potential regardless of the existing human uses or target areas with high conservation potential while minimizing impacts on existing activities;

7- Define the ***configuration of the network*** of closed areas (i.e. number and size of individual clusters), implemented in the prioritization approach by setting different values for the boundary penalty that penalises fragmented solutions using a matrix of shared boundary length between different PUs;

8- Define the ***prioritization targets*** which should include both the Spatial planning closure targets (i.e. the proportion of the spatial planning area to be included in the prioritization solutions) and the conservation features' representation targets;

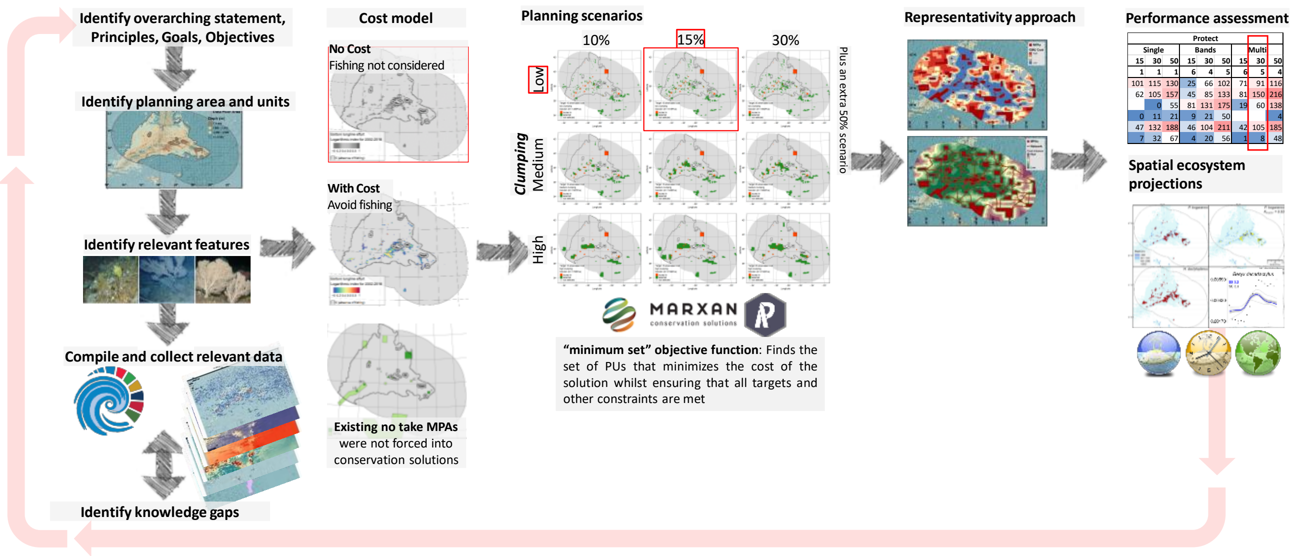
9- Implement a ***spatial prioritisation tool*** to complement the Important Areas with areas with Important Resources necessary to achieve the prioritization targets. Among many prioritisation tools, the "minimum set" approach, used by the Marxan software, is the most widely used framework in the world for informing marine and terrestrial protected area systems;

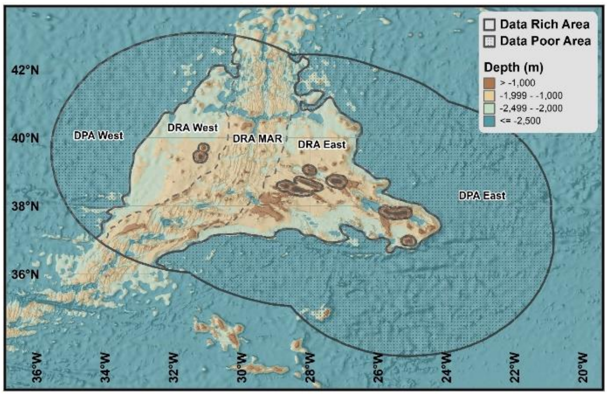
10- Preform a ***performance assessment*** of the planning scenarios solutions against the design criteria;

11- Forecast the ***ecosystem level outcomes***, including the human activities, of the implementation of scenarios;

12- ***Repeat the process*** until multiple options are evaluated and agreed or whenever new information is made available (i.e. Adaptive approach principle).

13- Complement the data-driven prioritization approach with a ***representativity and connectivity approach*** design to identify representative areas of all seabed habitats and to achieve the prioritization targets when information was considered to be inadequate or insufficient to justify a data-driven approach and to increase the connectivity of the whole network.





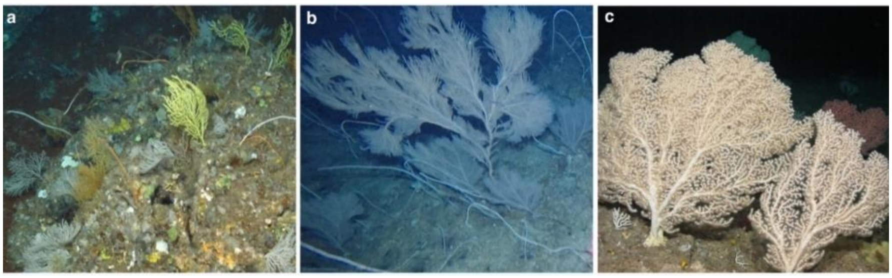
Therefore, the SCP for the deep-waters of the Azores was guided by a set of general principles, goals, objectives, and design criteria that determined the nature and characteristics of the scenarios developed. A spatial prioritisation approach was implemented with the PrioritizR package on the best available scientific information, acknowledging that substantial gaps in scientific knowledge still exist. Nevertheless, the SCP scenarios developed here, considered a range of conservation features, representation targets, cost, boundary penalties (proxy for size and number of conservation units), and constraints (e.g. existing area-based management rules). The spatial planning area was defined by the deep-water of the Azores EEZ divided into two sub-areas according to the data availability: a “data-rich planning area” shallower than 2,500m depth and a “data-poor abyssal planning area” deeper than 2,500m. We developed twenty-four different SCP scenarios, assessed the performance of each and forecasted the impact of potential area-based management initiatives on regional ecosystems using a spatial-oriented ecosystem-based model. These scenarios highlighted areas of special importance for management and conservation when considering potential MPA networks encompassing 10%, 15%, 30% or 50% of the planning area. They considered conservation designs of different complexity that on the one hand better captured biodiversity patterns and on the other hand were expected to facilitate the actual implementation of networks of closed areas (high, medium, and low clumping). Finally, these scenario considered two approaches; one targeting areas with high conservation potential but low fishing activities (fisheries-based cost scenarios), the other targeting areas with high conservation potential regardless of existing human activities (area-based cost scenarios).

Important management and conservation features

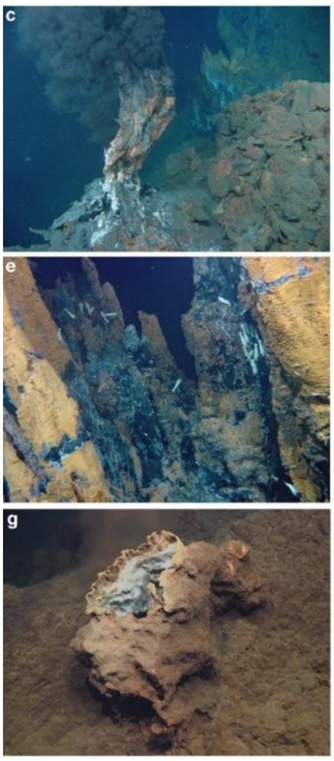
We considered different management and conservation features including important areas and important resources. Important areas, i.e. ecologically or biologically important, were also included in the systematic conservation planning approach. Essential fish habitat (EFH) represent those waters and substrates essential to the ecological and biological requirements for critical life-history stages of exploited fish and, therefore, necessary to fish for spawning, breeding, feeding, growth to maturity, or for migrations. Sedlo and the Hard Rock Cafe seamounts have been considered an EFH because of the observations of massive reproductive aggregations of fish species, such as the orange roughy (*Hoplostethus atlanticus*), splendid alfonsino (*Beryx splendens*) and cardinalfish (*Epigonus telescopus*). Although insufficient information exists regarding what should be considered an essential fish habitat in the Azores, these two areas have been included as important areas in the prioritization approach.

Areas with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation have been regarded as important reference sites that can help setting conservation goals and objectives, guiding trajectories of recovery of impacted sites, and inform adaptive management. The analysis of Vessel Monitoring System (VMS) data indicates that all geomorphologic features shallower than 1000m in the Azores region have been fished to some extent. However, new multibeam bathymetry surveys south of the Flores islands have revealed that the small Diogo de Teive seamount is much shallower than previously thought, and has no indication of fisheries exploitation. Although a careful examination of the deep-sea benthic communities inhabiting this seamount could give more insights in the levels of potential fishing impacts, this seamount has been included as an important area in the prioritization approach as the only near-natural area in the Azores.

Regardless of their faunal composition, some scientists have suggested that seamounts should be managed as VMEs because of the perceived rich biodiversity and vulnerability to human activities. Shallow seamounts (summits below 250m depth) may be considered important areas because of their benthic communities, ecological role for demersal fish, and resilience potential towards climate change, as well as biodiversity hotspots for large pelagic megafauna. Deep seamounts, located in abyssal plains, are less known but possibly function as hidden sources of increased habitat heterogeneity, acting as valuable biodiversity reservoirs in the large abyssal plain. For these reasons, the identification and protection of very shallow and very deep seamounts was considered relevant to address management objectives related to protect hotspots of biodiversity, maintain biological diversity, and rebuild fish stocks. Eleven shallow water seamounts located in the "data-rich" area were included in the prioritization approach: Açor, Condor, Don João de Castro, Formigas, Gigante, Gigante 127, Grande Norte, Mar da Prata Norte and Sul, Princesa Alice and Voador. One deep seamount, deeper than 1500m, was identified in the "data-rich" area and considered as important because of its uniqueness.

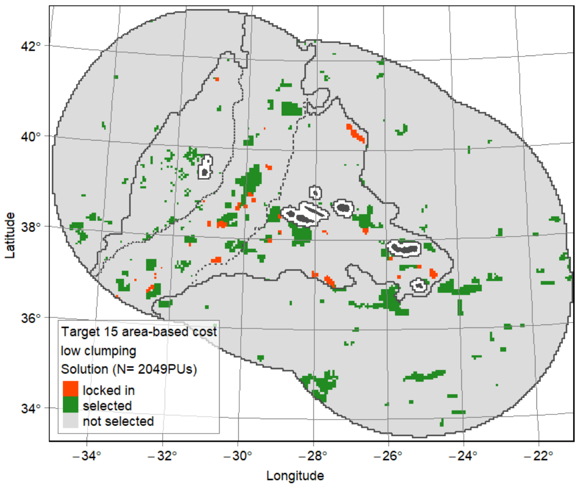


According to FAO, the identification of Vulnerable Marine Ecosystems should be based on the assessment of several well-known criteria. Unequivocal VMEs in the Azores were defined as those areas that meet such criteria after a sound scientific exploration through the analysis of video transects recorded during oceanographic cruises. Based on the composition, size-structure and distribution of their main benthic communities, 28 underwater features, including seamounts, ridges and slopes around the Azores islands, were assessed against each of the five FAO criteria. A total of 12 features were identified as priority areas for conservation, consisting of 3 portions of the MAR (Western ridge, Ridge east of Gigante and Cavalo) and eight seamounts (Oscar, Gigante, Cavala, Beta, Voador, Condor, Don João de Castro, and Formigas), and an area with several small mounds south-east of Pico island. The deep-sea around Capelinhos (Faial island) was also identified as priority but not included in the prioritization approach since they are located in the coastal areas and therefore outside the spatial planning area. In general, all these features were characterized by a great diversity of species and biological communities, some degree of uniqueness, fragility, and communities that provide complex habitat for other species. Hydrothermal vent fields are also recognized as important VMEs due to their specific physical and geologic setting, with high rates of endemic species. Ten hydrothermal vent areas located inside the planning area were considered in the prioritization approach as important areas, namely Saldanha, Famous, Lucky Strike, Menez Hom and South Lucky Strike, Menez Gwen and Bubbylon, Luso, Don Joao de Castro, and South Kurchatov.

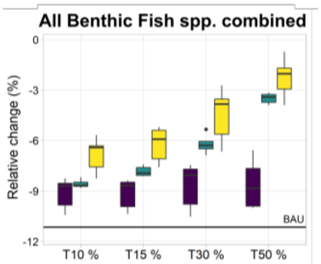


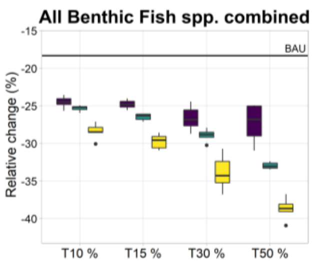
Important resources are defined here as those species, habitats or functions considered most suitable to achieve the management and conservation goals. To address important resources related objectives, we compiled the best available scientific data on the known occurrence and predicted distribution of commercially important benthic deep-sea fish, endangered or critically endangered deep-water sharks, vulnerable cold-water coral species, the distribution of known essential habitats, VME indicators, together with inferred indexes of VME likelihood.

Summary of the systematic conservation planning outputs



The systematic conservation planning for the deep-water of the Azores, suggested the prioritization outputs are highly dependent on the goals and objectives adopted. It also highlighted that the prioritization outputs, but also the performance assessment and the forecasted impact of management measures depend on the range of conservation features, representation targets, cost model, boundary penalties, and constraints considered. In general terms, besides the important areas locked-in the solutions, the resulting network of priority areas is spread throughout the whole EEZ, with a better coverage of all important management and conservation features in scenarios with low and medium clumping. When fishing activities were not considered in the scenarios (area-based cost scenarios), potential MPA networks had a better representation of shallow water depths while scenarios that attempted to reduce the overlap of fishing activities and conservation measures (fisheries-based cost scenarios) showed that potential MPA networks were displaces into deeper waters. Not surprisingly, area-based cost scenarios included more fish suitable habitat in the solutions than the fisheries-based cost solution. Fisheries-based cost scenarios, generally reduced the overlap with existing fishing footprint and existing fishing effort.

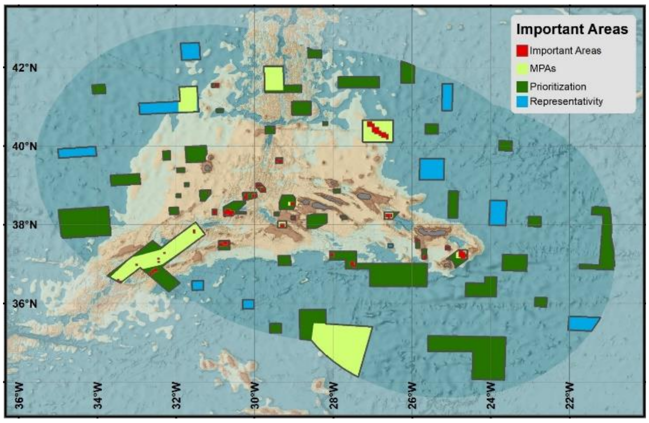




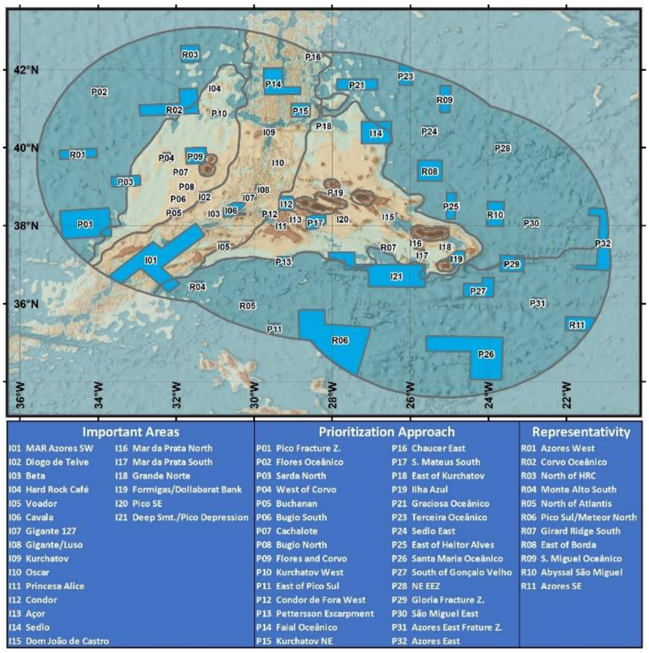
The overarching conclusion of the forecasted ecosystem outcomes is that networks of MPAs in the Azores can have strong positive effects in the biomass of top-predators, and lead to spatial trophic cascade effects through the food-web. However, significant changes in the structure and likely functioning of the ecosystem were restricted within the reserves. Our model projections also suggested that the implementation of “no-take areas” in the deep-sea may require longer time-frames. The projected smaller increase in biomass of many fish species when compared to other studies might be related to the fact that most deep-sea species will take longer to recover due to their life-history characteristics. Additionally, due to the complex topography of the Azores EEZ, the spillover effects to neighbouring cells might be limited in off-shore and deep-water grounds, as the adjacent areas might not be suitable habitats and therefore lead to weak spillover effects. Consequently, closed areas that safeguard connectivity to suitable habitats (e.g. seamounts, island slopes) might reduce the time-frames required for recovery of deep-sea environments and be more appropriated to sustain fisheries catches.

Our model also projected that the implementation of “no-take areas” should be accompanied by other fisheries management measures. We noted that the implementation of a MPA strategy projected potential detrimental effects in some shallow-water and coastal commercially important fisheries stocks. This may result from the displacement of fishing effort to coastal and shallower fishing grounds, with potentially negative effects on some fish stocks. This aspect highlights the need for specific prioritization approaches for the coastal areas and coastal and shallow water biodiversity. Notwithstanding, complementing fisheries closed with additional fisheries management measures (e.g., fishing effort reductions) might be crucial to avoid negative effects in some shallow-water fishing stocks and to achieve management ecosystem-based management goals.

Simplified prioritization solutions

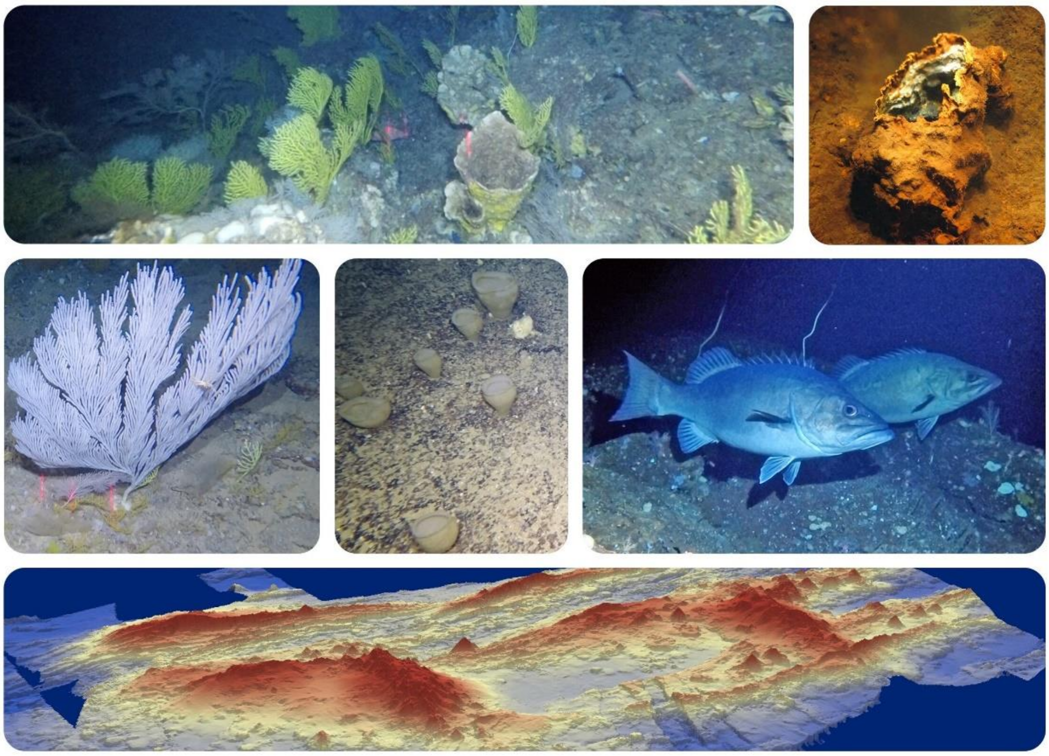


The simplified and complemented network of priority areas successfully increased the representativity of all seabed habitats and the connectivity across the entire spatial planning area, and helped to achieve the all prioritization targets. The simplification of the systematic conservation planning scenarios developed to address the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores resulted in 62 and 63 priority areas for management and conservation for the area-based cost and varying fisheries-based cost models, respectively. The networks resulting from this complex approach is composed of: 21 Important Areas that based on current best available knowledge (data-driven approach) are features of particular ecologically or biologically importance and the most suitable to achieve the planning goals; 29-30 areas resulting from the prioritization approach; and 11-14 areas resulting from the complementary approach to increase the representativity and connectivity of the networks. We developed summary factsheets for the resulting list of priority areas that synthetize the best-available information that originated their designation and may stimulate the discussions. It should be stressed again that the objective of this list is not to indicate the preferred design and placement of fisheries closures in the Azores, but rather to summarize the outputs of the systematic conservation planning approach and to inform the discussions around this topic.



Ways forward

It should be highlighted that, although there has been large of number of scientific research in recent years that substantially increased scientific knowledge in the Azores, there still exist some fundamental knowledge gaps hampering the proper development of systematic conservation planning approaches aimed at informing the development of policies that promote the sustainable use of deep sea natural resources. This work highlights, once again, the need for creating a long-term strategy for advancing deep-sea scientific knowledge to fill many of the knowledge gaps and contribute with scientific data to inform the development of policies that promote the sustainable use of deep-sea natural resources and support Maritime Spatial Planning. Such long-term strategies should translate into a clear effort to increase scientific knowledge of the Azores deep sea, notably by continuing efforts to map the Azorean seafloor and the communities living there. However, this will only be possible if the Azores are provided with the appropriate infrastructures and technological means but also long-term, stable, and predictable scientific careers for current and future scientists. Finally, this work also calls for a long-lasting commitment of the local stakeholders to protect marine life, so the Azores continue its role as a leading example of how to reconcile marine conservation with sustainable use of the ocean and how to implement marine conservation with important consequences for the region.



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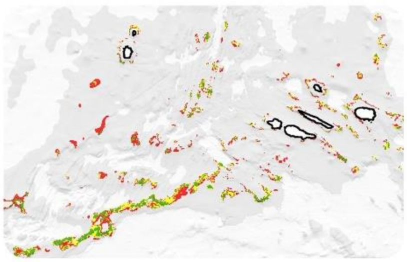

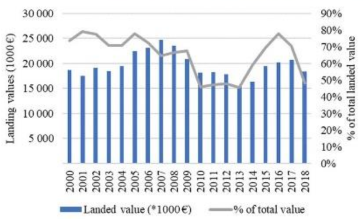

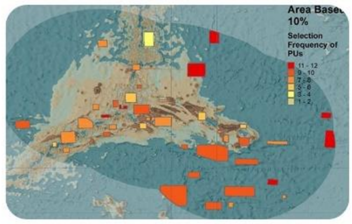

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23 November 2023

Contents

List of acronyms used:

ABMT - Area-Based Management Tools
ABNJ - Areas Beyond National Jurisdiction
APEI - Areas of Particular Environmental Interest
ATJ - Azores Triple Junction
BAU - Business as usual
BBNJ - Biological diversity of Areas Beyond National Jurisdiction
BLL - Bottom Longline
BPI - Bathymetric Position Index
CBD - Convention on Biological Diversity
CFP - European Common Fisheries Policy
CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMIP5 - Coupled Models Intercomparison Project Phase 5
COLETA - University of the Azores' Marine Biological Reference Collection
CWC - Cold-water corals
D - Depression
DLR - Decreto Legislativo Regional
DRAM - Regional Directorate for Maritime Affairs
EBSA - Ecologically or Biologically Significant Area
EEZ - Exclusive Economic Zone
EFH - Essential Fish Habitat
EMEPC - Estrutura de Missão para a Extensão da Plataforma Continental
EU - European Union
FA - Flat Areas
FAO - Food and Agriculture Organization
FE - Fishing Effort
FO - Fishing Operation
FSRA - Fish Stock Recovery Areas
GAM - Generalized Additive Models
GEOBIA - Geographic Object-Based Image Analysis
GMU - Geomorphic Management Unit
HI - Hill and Lower slopes
HL - Handline
HR - High Relief
HRU - High Relief Unit
HSI - Habitat Suitability Index
HSM - Habitat Suitability Models
ICCAT- International Commission for the Conservation of Atlantic Tunas
ICES - International Council for the Exploration of the Sea
IEO - Instituto Español de Oceanografía
IFREMER - Institut Français de Recherche pour l'Exploitation de la Mer
IH - Instituto Hidrográfico
IMAR - Instituto do Mar
IPCC - Intergovernmental Panel on Climate Change
IS - Island Shelf
ISA - International Seabed Authority
ISU - Island Shelf Unit
IUCN - International Union for Conservation of Nature
LHP_FIF – Pole-and-line métier
LLS_DEF – Set longline gear métier
LO - Landing Obligation
LR - Low Relief
LRU - Low Relief Unit
MAR - Mid-Atlantic Ridge
MARNA - Mid-Atlantic Ridge north of the Azores
MIBAs - Marine Important Bird Areas
MLS - Minimum Landing Size
MPA - Marine Protected Area
MSFD - Marine Strategy Framework Directive
MSS - Maximum Sensitivity and Specificity
MSY - Maximum Sustainable Yield
NAFO - Northwest Atlantic Fisheries Organization
OSPAR Convention - Convention for the Protection of the Marine Environment of the North-East Atlantic
PMA - Parque Marinho dos Açores
PU - Planning Unit
RCP - Representative Concentration Pathway (for IPCC scenarios)
RFMO - Regional Fisheries Management Organization
ROV - Remotely Operated Vehicles
RPN - Relative Population Number
SAC - Special Area of Conservation
SCI - Sites of Community Importance
SCP - Systematic Conservation Planning
SMART - Specific, Measurable, Achievable, Relevant or Realistic, and Time-bound
SMS - Seafloor Massive Sulphide
SPICT - Surplus Production in Continuous-Time model
SST - Sea Surface Temperature
STECF - EU Scientific, Technical and Economic Committee for Fisheries
TAC - Total Allowable Catch
UAç - Universidade dos Açores
UN - United Nations
UNCLOS - United Nations Convention on the Law of the Sea
UNESCO - United Nations Educational, Scientific and Cultural Organization
UNGA - United Nations General Assembly
VME - Vulnerable Marine Ecosystem
VMS - Vessel Monitoring System
WGDEC - Working Group on Deep-water Ecology
WGDEEP - ICES Working Group on the Biology and Assessment of Deep-sea Fisheries Resources

1. Introduction

Area-based management has been widely advocated as an effective instrument for protecting and preserving the marine environment while enabling the sustainable use of marine resources. Area-Based Management Tools (ABMT) may include multi-sectoral elements such as Marine Spatial Planning (MSP), integrated coastal management, and Marine Protected Areas (MPAs), or single-sectoral elements such as for example fisheries closures, and Areas of Particular Environmental Interest (APEI) in the context of deep-sea mining (UNEP & GEF-STAP, 2014). MPAs, including fisheries closures, can help achieving multiple ecosystem-based management objectives such as the conservation of species, habitats and ecosystem services, increased fisheries yield (e.g. increased abundance, species diversity, and "spill-over" effects), and increased tourism, recreational, and educational opportunities. When taking climate change into consideration, MPAs become important tools to mitigate the accelerated loss of biodiversity on marine ecosystems which are vulnerable to global warming and ocean acidification (IPBES, 2019; IPCC, 2019).

However, the expected outcomes of different area-based management decisions, as MPAs, are highly dependent on spatial location and design of such implementation. Therefore, solutions randomly applied across the marine environment may jeopardize achieving the desired management objectives. Systematic Conservation Planning (SCP), based on the best available data and specific management and conservation goals, can inform choices about areas to protect in order to optimize outcomes and reduce conflicts transparently and objectively (Margules & Pressey, 2000). Such approach allows not only to evaluate the location of priority areas for conservation in relation to the heterogeneity of the marine environment but also to inform the design of the conservation network, which includes the size, connectivity, and replication. Systematic Conservation Planning approaches have been used to inform marine spatial planning worldwide, with notable examples in the Gulf of California (Álvarez-Romero et al., 2013; Gleason et al., 2013), the Great Barrier Reef (Fernandes et al., 2005), the Coral Triangle (Asaad et al., 2018; Green et al., 2009; Jumin et al., 2018), the Mediterranean Sea (Giakoumi et al., 2013; Mazor et al., 2014; 2016; Micheli et al., 2013), and the Benguela Current Large Marine Ecosystem (Kirkman et al., 2019). Despite the multiple efforts to develop SCP initiatives (http://database.conservationplanning.org; Álvarez-Romero et al., 2018), this approach has rarely been applied in the deep-sea. However, Wedding et al. (2013) and Dunn et al. (2018) developed SCP to inform spatial management and zoning of the deep sea to the International Seabed Authority in the context of deep-sea mining. Additionally, Clark et al. (2014) developed systematic approaches to inform the identification of candidate seamounts that satisfied the Ecologically or Biologically Significant Areas (EBSA) criteria (CBD, 2009). Finally, the H2020 ATLAS project developed SCP at the North Atlantic spatial scale to inform the identification of priority areas for the conservation of Vulnerable Marine Ecosystems (Combes et al., 2019; in prep.) Very recently, several complementary approaches have used SCP approaches to identify priority areas for marine biodiversity conservation in areas beyond national jurisdiction (ABNJ) at a global scale (O'Leary et al., 2019; PEW, 2020; Visalli et al., 2020). These approaches have been used to inform the discourse around the protection of least 30% of marine environment while avoiding areas of high fishing intensity.

Several marine protected areas with fisheries restrictions have been implemented in the Azores since the 1980's, with the Condor seamount being the most well-known and successful case. The Condor seamounts closed area (240 km^2) was designated as a temporary protected area for research in June 2010 (Morato et al., 2010; Giacomello et al., 2013). The decision to close this seamount to fisheries arose from a collaborative, bottom-up process involving scientists, local fishers, tourist operators and the Regional Government of the Azores (Giacomello et al., 2013). Over the last eight years, this MPA has been monitored for the abundance of fish stocks, and the results have been shared with all relevant stakeholders. Signs of fish stocks recovery have been observed since the early years (Menezes et al., 2013; Giacomello, unpublished data), which has helped convincing stakeholders to keep the Condor seamount closed to fishing, but most importantly, to try similar approaches in other areas within the Azores Exclusive Economic Zone (EEZ). The fisheries sector along with the Regional Government of the Azores demonstrated interest in implementing some fisheries closures in Mar da Prata with the main objective of rebuilding commercially important fish stocks in this perceived overfished area.

More recently, the Regional Government of the Azores, the Oceano Azul Foundation, and the Waitt Institute signed a memorandum of understanding over the "Blue Azores" Program, focused on promoting the conservation and sustainable use of resources, by declaring 15% of the Exclusive Economic Zone of the Azores as new marine protected areas. The implementation of such closures may have very different short-, medium- and long-term outcomes depending on the extent (size), design (shape), and location (placement and spacing) of such closures (Green, et al., 2014). Here, we used systematic conservation planning techniques to develop multiple fisheries closures scenarios to inform the selection of "no-take areas" for achieving certain conservation and management goals in the **deep-sea** of the Azores Exclusive Economic Zone (EEZ). This report aims to inform the discussions around the designation of 15% of the Exclusive Economic Zone of the Azores as new marine protected areas.

2. The Azores deep-sea case study

2.1 The Azores deep-sea ecosystem

The Azores is an oceanic archipelago in the mid-North Atlantic Ocean, between continental Europe and North America. The seafloor is mostly deep, but several topographic elevations (e.g. seamounts, a fraction of the Mid Atlantic Ridge) and the slopes of the islands compose the shallowest parts. After the first expeditions to the deep sea in the late 19th and early 20th centuries lead by Prince Albert I of Monaco (Porteiro, 2009; Santos et al., 2009a), extensive scientific research-based in the Azores has opened a window on the functioning of large deep-sea ecosystems and the impacts of human activities in such ecosystems. The Azores have, therefore, a long history of deep-sea research, recently supported by various regional (e.g. 2020, MapGES, DeepWalls, FunAzores, PlastDeep, Impactor, RECO), national (e.g. DeepData, Ecomining JPIOceans), and European funded research projects and international collaborations (e.g. OASIS, HERMIONE, CoralFISH, DiscardLess, ATLAS, MERCES, SponGES, iAtlantic, EMSODEV). This research, carried out at IMAR and Okeanos of the University of the Azores, consolidated the knowledge about seamounts, ridges and hydrothermal vent ecosystems at the global and local scales. Over the last decades, new deep-sea species, biotopes, hydrothermal vent fields, and ecological associations were discovered (e.g. Carreiro-Silva et al., 2017; de Matos et al., 2014a,b; Tempera et al., 2015; Gomes-Pereira et al., 2017; Pham et al., 2015), and even new genes with potential for biotechnology (Martins et al., 2014; Bettencourt et al., 2017).

However, substantial gaps in scientific knowledge still exist that may hamper the proper development of systematic conservation planning approaches and the development of policies that promote the sustainable use of deep-sea natural resources. Therefore, we continue to develop new tools that allow the exploration of unknown areas in the Azores EEZ, and to develop knowledge that allows unveiling some important ecological paradigms, such as those related to ecosystem functioning, connectivity, adaptations and the evolution of deep-sea ecosystems. Uncovering the vulnerability and resilience of these communities to mineral exploitation or climate change, and the contribution of the deep sea to carbon sequestration, climate regulation and other ecosystem services have also recently emerged as important areas of research.

Nevertheless, the scientific research centred in the Azores helped to raise awareness on the need to improve management and governance of open-ocean and deep-sea ecosystems. This research has been instrumental in informing and supporting marine policy at Regional, National, European, and International levels. For example, relevant knowledge has been transferred to the Regional Government of the Azores to provide fisheries management advice and advice for the implementation of a network of marine protected areas in the Azores, as for example the establishment of a roadmap for implementing the MSFD for the sub-region of Macaronesia or the provision of scientific information to the proposals of management plans for many Natura 2000 sites. Scientific information has also been transferred to the International Commission for the Conservation of Atlantic Tunas (ICCAT), to the International Council for the Exploration of the Sea (ICES), to the OSPAR commission, the Sargasso Sea Alliance, or even the European parliament.

Additionally, relevant knowledge has been transferred to several regulatory processes under the United Nations (UN) Convention on the Law of the Sea (UNCLOS), namely on the Preparatory Committee for the development of an international legally binding instrument on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ). Scientific advice on cetacean conservation status or the EBSA process has been delivered to The Convention on Biological Diversity (CBD) and on vulnerable marine ecosystems to the CBD and the International Seabed Authority (ISA). Commentaries and annotations to the "Discussion Paper" on environmental regulations to govern deep-sea mining exploration and exploitation contracts were offered to the ISA. Scientific knowledge on the likely effects of climate change on fisheries and deep-water vulnerable marine ecosystems were transferred to the UN Food and Agriculture Organization (FAO) (Levin et al., 2019).

2.1.1 General setting (location) of the Azores

The Azores is an archipelago of nine volcanic islands spreading along a NW–SE-trending strip of 600-km long, with the Mid-Atlantic Ridge (MAR) separating the islands of Flores and Corvo, to the west, from the remaining island groups (Figure 1). Portugal's marine jurisdiction around the islands encompasses an Exclusive Economic Zone of almost 1 million km^2 of which about 99% is deep sea (>3000 m; Appendix 1.1.1), and a claimed continental shelf extension that expands Portuguese sovereignty to approximately twice this value. The islands of recent origin (Feraud et al., 1980) rise from volcanic edifices sitting on an elevation roughly delineated by the 2000-m depth contour and named the Azores Plateau, laying above the tectonically active Azores triple junction (ATJ) between the North American, Eurasian and African plates (Searle, 1980; Lourenço et al., 1998). The main tectonic features in the region are (i) the Mid-Atlantic Ridge (MAR), which crosses the Azores Plateau in a path approximately North-South and (ii) the Terceira Rift which crosses WNW-ESE to NW-SE direction and defines the NE margin of the plateau (Lourenço et al., 1998; Vogt & Jung, 2004; Appendix 1.1.4). The Azorean section of the MAR is a spreading centre that separates the North American plate from the Eurasian and African plates (Searle 1980). Terceira Rift is an ultra-slow spreading ridge, which is thought to operate as the present Eurasian and African plate boundary along much of its extent (Vogt & Jung, 2004).

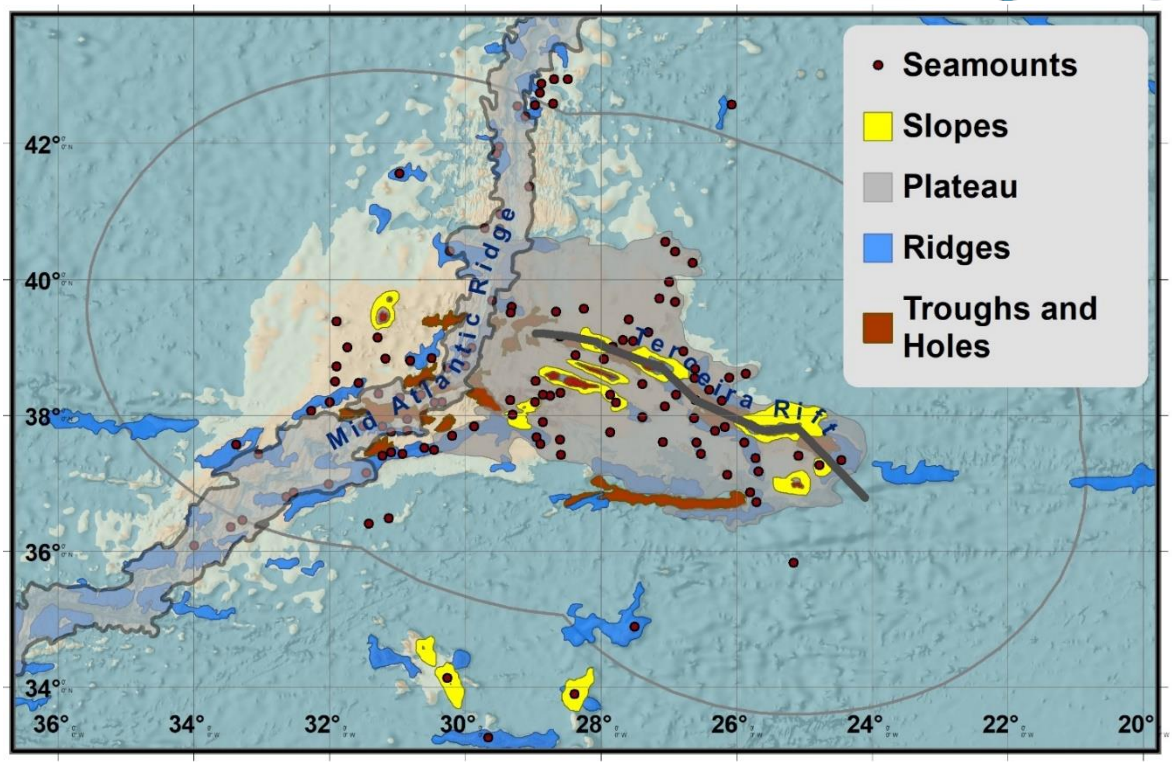


Figure 1. Map of the Azores showing the main tectonic features in the region, the Mid-Atlantic Ridge and Terceira Rift, and other geomorphologic structures of the seafloor (e.g. seamounts, slopes, plateaus, ridges, throughs and holes).

The seafloor surrounding the islands is characterized by a diverse topography comprising island slopes, seamounts, deep fracture zones, trenches, a considerable extension of the Mid-Atlantic Ridge (MAR) and abyssal plains exceeding 5,000m depth. Seamounts are prominent topographic features in the Azores, with 460 seamount-like features that may occupy 37% of the EEZ (Morato et al., 2008; 2013; Appendix 1.1.2). The physical characteristics of the seafloor surrounding the Azores Archipelago is compiled in Perán et al., (2016).

2.1.2 Brief physical and oceanography description

The archipelago is located on the inter-gyre region of the eastern North Atlantic between 34º and 50ºN, which shapes the complex oceanographic environment of the Azores (Maillard, 1986, Amorim et al., 2017). Large-scale circulation is influenced by two eastward currents branching from the Gulf Stream: the cold North Atlantic Current in the north, crossing the Mid-Atlantic Ridge between 45-48 48ºN (Bower et al., 2002), and the warm Azores Current to the south, which crosses the MAR between 34-36ºN (Alves & Verdière 1999; Bashmachnikov et al., 2004; Martins et al., 2008). Almost permanent complex mesoscale eddies with meanders and resurface circulation pattern related topographical features are also important oceanographic features in the region (Reverdin et al., 2003; Caldeira & Reis, 2017). In deeper waters, numerous water masses can be located: the North Atlantic Central Water from ca. 150 to 500 m depth; the Northern Sub-Polar Water at ca. 500-700 m depths, the Mediterranean Outflow Water at ca. 700-1300m and the North Atlantic Deep Water below 2000 m depth (Johnson & Stevens, 2000; Bashmachnikov et al., 2009). The eastward-flowing Azores Current is considered as the northern limit of the North Atlantic Subtropical Gyre (Juliano & Alves, 2007).

The Azores is a transitional region between subtropical and temperate climate, experiencing large scale spatial and seasonal variation of oceanographic conditions (Lafon et al., 2004). The sea temperature is characterized by horizontal gradients enhanced by the cold North Atlantic Current and the Azores Current flows (Bashmashnikov et al., 2004). Average sea surface temperature ranges from 15ºC in the winter 27ºC in the summer (Martins et al., 2008; Amorim et al., 2017). A deep mixed layer is present at ~150m depth during the winter, while a seasonal thermocline usually develops between 40 and 100m depth in the summer (Santos et al., 1995). In general, productivity is low, but localized upwelling associated with island slopes and seamounts can enhance local production (Bashmachnikov et al., 2004, Morato et al., 2008; 2009), with maximum values in the winter and spring and minimum values in the summer (Santos et al., 2013). Datasets of environmental data for the Azores region from remote sensing and in situ data (e.g. temperature, salinity, chlorophyll-a, organic and inorganic carbon) are compiled in Amorim et al. (2017) and presented in Appendix 1.2.1 and 1.2.2.

2.1.3 Biological diversity and uniqueness of the Azores deep-sea

Several areas of the Azores may fit the FAO criteria for defining Vulnerable Marine Ecosystems (VME) while others may be considered priority habitats in need of protection by the OSPAR Convention for the protection and conservation of the North-East Atlantic. These include seamounts (OSPAR, 2010a), ocean ridges with hydrothermal vents (OSPAR, 2010b), coral reefs (OSPAR, 2009) and coral gardens (OSPAR, 2010c) and deep-sea sponge aggregations (OSPAR, 2010d).

Hydrothermal vents

Deep-sea hydrothermal vents represent one of the most physically and chemically unique biomes on Earth (Takai & Nakamura, 2011). They are regions of the ocean floor where high-biomass invertebrate communities are fuelled by the emission of fluids from below the seafloor. The energy provided as a flux of reduced inorganic chemicals (e.g. sulphide, methane, and hydrogen) allows chemoautotrophic production by the fixation of carbon from CO_2 by symbiotic and free-living chemolithoautotrophic microorganisms, which form the base of the food web (Tunnicliffe et al., 2003; LeBris et al., 2019). Furthermore, hydrothermal processes control the transfer of energy and matter from the earth core to its crust, hydrosphere and biosphere (Pirajno & Kranendonk, 2005). The vent circulation accounts for approximately one-third of the global geothermal heat flux to the oceans and strongly affects the chemical composition of the water (Elderfield & Schultz, 1996).

The MAR host hydrothermal vents in the Atlantic, with five known vent fields located in the Portuguese EEZ around the Azores (Beaulieu & Szafranski, 2019), relatively close to each other and to the Azores islands (Figure 2; Appendix 1 1.3). These are the Menez-Gwen (at 850 m depth) including Bubbylon, Lucky Strike (1700m) including Ewan, Menez Hom (1800 m), Saldanha (2300 m), and Luso (570 m), as well as Rainbow (2400 m) in the claimed Extended Continental Shelf (Figure 3, Table 1). Dom João de Castro is a shallow-water hydrothermal vent (20 m) associated with the hyper-slow spreading Terceira Rift. The detection of several hydrothermal plumes signal on the northern MAR may indicate that more active fields may occur in the region (Hydes et al., 1986; German et al., 1996; Chin et al., 1998; Aballea et al., 1998), and at estimated rates of ~1 site every 100km for slow-spreading ridges like the Atlantic (Baker et al., 2004; 2016). These hydrothermal vent fields exhibit a wide range of environmental conditions, including considerable variation in depth and associated physical parameters, and different geologic setting and underlying rocks. These factors affect the fluid composition and subsequently the type of hydrothermal vent communities, often resulting in unique faunal assemblages associated with different hydrothermal vents (Desbruyères et al., 2000; 2001).

The three main high-temperature deep-sea hydrothermal vent fields in the Azores Triple Junction, the Menez Gwen, Lucky Strike and Rainbow vent fields are the most well-studied of the Azores concerning fluid chemistry (Langmuir et al., 1997; Charlou et al., 2000; Charlou et al., 2002; Douville et al., 2002; Seyfried et al., 2011), geologic setting (Humphris et al., 2002; Ondreas et al., 2009), deposit mineralogy and macrobiological communities (Colaço et al., 1998; Desbruyères et al., 2000; 2001; Cuvelier et al., 2009; Bettencourt et al., 2014), trophic ecology (Colaço et al., 2002; 2006a; 2007; 2009; Riou et al., 2008), and microbiology (Wery et al., 2002; Byrne et al., 2009; Flores et al., 2011; Cerqueira et al., 2015; 2017). The Menez Gwen and Lucky Strike vent systems are located on axial seamounts and on a relatively shallow portion of the MAR, at 850 and 1700 m depth, respectively. Both are basalt-hosted fields influenced by an area of enhanced melt production in the mantle (Parson et al., 2000). By contrast, the Rainbow field, located at 2300 m depth, is associated with upper-mantle ultramafic rocks. In these high-temperature fields, the hot (up to 400 °C) vent fluids are enriched in metals and generate black smoker chimneys on the seafloor (Table 1). Fluid chemistry composition in Menez Gwen and Lucky Strike is characterized by a high concentration of hydrogen sulfide (H_2S), whereas fluid composition in Rainbow shows a dominance of methane (CH_4) and low pH (Charlou et al., 2000, 2002).

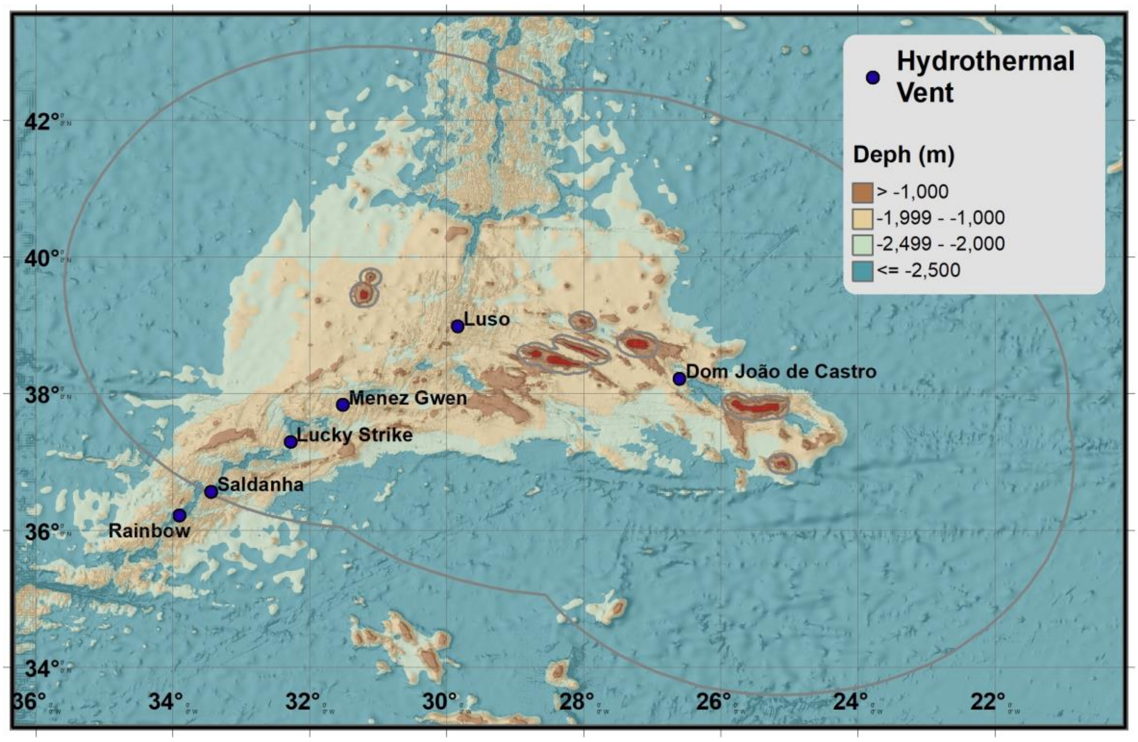


Figure 2. Location of the main hydrothermal vents fields in the Azores: Menez Gwen, Lucky Strike, Rainbow, Saldanha, Luso and Dom João de Castro.

The faunal composition (Figure 3) in Menez Gwen is dominated by large colonies of *Bathymodiolus azoricus* mussels which cohabit with limpets (e.g. *Lepetodrilus atlanticus* and *Protolira valvatoides*), shrimps (*Chorocacis chacei* and *Mirocaris fortunata*), and crabs (*Segonzacia mesatlantica*, *Chaecon affinis*) (Colaço et al., 1998). Fauna assemblages in the Lucky Strike hydrothermal vent field are dominated by shrimp aggregations of *Mirocaris fortunata* and *Chorocaris chacei* living close to the vent outflows, and dense beds of *Bathymodiolus azoricus* mussels widely distributed within the field, generally in warm diffuse venting zones (Desbruyères et al., 2000; 2001). Faunal communities in the Rainbow hydrothermal vent field are composed of the shrimps *Rimicaris exoculata* and *Mirocaris fortunata*, whereas *Bathymodiolus azoricus* and *Bathymodiolus seepensis* mussels dominate the faunal communities on surrounding blocks within the active area (Desbruyères et al., 2000; 2001).

In contrast to the above-mentioned vent fields, the Saldanha, Luso and Dom João de Castro hydrothermal vents are characterized by low-temperature hydrothermal activity. The Saldanha hydrothermal field is hosted atop a mafic–ultramafic seamount (2200–2300 m deep) within a non-transform offset between the Famous and Amar segments on the MAR (Barriga et al., 1998). The vents are scarce and scattered on the ocean floor and are characterized by the discharge of a clear fluid through centimetre-sized orifices without the growth of chimney-like or other structures (Barriga et al., 1998; Dias & Barriga, 2006). Fluid temperatures are 7-9°C with a detected methane anomaly, but no data on fluid chemistry (Barriga et al., 2003). No benthic vent macrofauna is present at the active site, while the presence of methanotrophic bacteria is suspected but remains to be confirmed (Barriga et al., 2006). In the vicinity of the active venting site, large concentrations of sessile invertebrates, in particular hexactinellid sponges, hydroids, gorgonians, alcyonarians and stalked crinoids, can be found on the edge of basaltic crests where currents are high (Barriga et al., 2006).

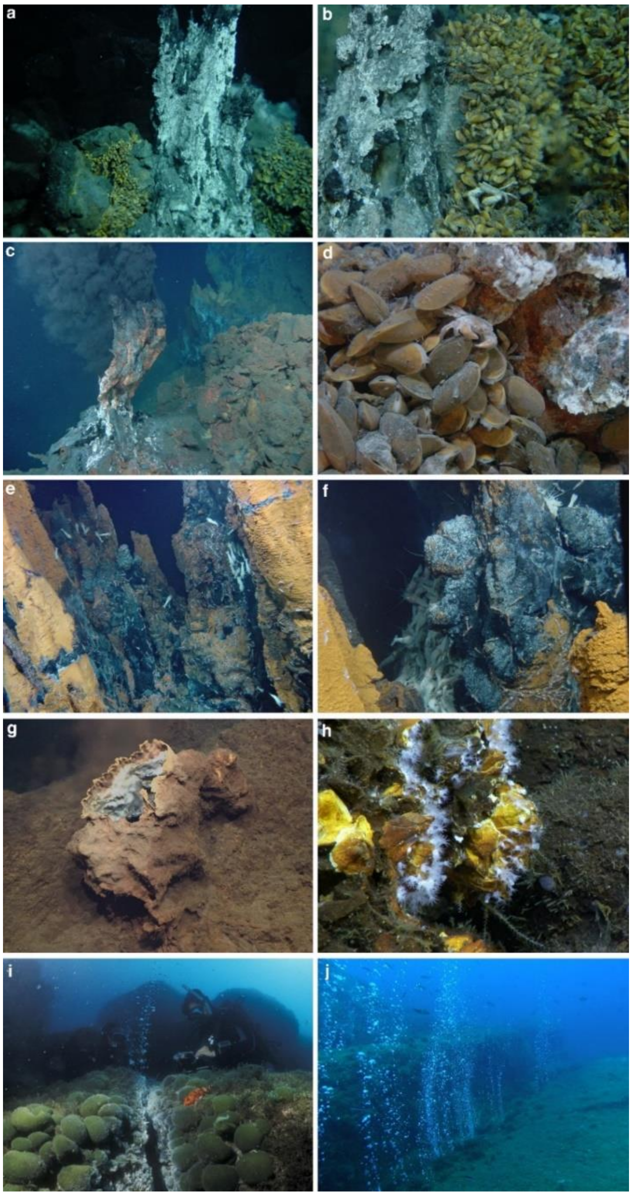


Figure 3. Hydrothermal vent fields in the Azores. (a) Menez Gwen vent field at 850 m depth with (b) macrofaunal communities dominated by *Bathymodiolus azoricus* mussel beds; (c) Lucky Strike hydrothermal vent field at 1600 m depth; with (d) *Bathymodiolus azoricus* mussel beds, shrimp *Mirocaris fortunate* and crab *Segonzacia mesatlantica*; (e) Rainbow hydrothermal vent field at 2300 m depth; with (f) shrimp aggregations of *Mirocaris fortunata* and *Chorocaris chacei* living close to the vent outflows; (g) Luso hydrothermal vent field with (h) associated non-typical chemoautotrophic fauna, composed of tubicoulous amphipods, balanomorph barnacles and zoantharia; (i-j) Dom João de Castro hydrothermal vent field at 20 m depth, dominated by macroalgae assemblages. a,b © AtosMisson2001, IFREMER; c © MoMARETO2006, IFREMER; d, e, f © SEAHMA2002, FCT/PDCTM/MAR/15281/1999; g © ROV Luso/EMEPC/2018 Oceano Azul Expedition; h © Viktor 6000, IFREMER/CNRS, i.JFONTES©ImagDOP/UAz, j JXAVIER©ImagDOP/UAz.

Table 1. Distinctive geological, geochemical and ecological characteristics of the main hydrothermal vent fields in the Azores. Dominant gas in fluids and fauna in bold.

Vent field	Geology	Depth (m)	Fluid chemistry	pH	T ºC	Biological communities
Menez Gwen	Basalt	850	**H_2S**, CH_4, CO_2	4	280	Mussel ***Bathymodiolus azoricus*** and shrimp aggregations of *Mirocaris fortunata*
Lucky Strike	Basalt	1603	**H_2S, CO_2**, H_2 CH_4	3.7	330	Mussels ***Bathymodiolus azoricus*** and shrimp aggregations of *Mirocaris fortunata* and *Chorocaris chacei*
Rainbow	Ultramafic	2362	**CH_4, H_2,** H_2S, CO_2	2.8	360	Shrimp aggregations of ***Rimicaris exoculata*** and ***Mirocaris fortunata***, mussel *Bathymodiolus azoricus*
Saldanha	Ultramafic	2300	**No data; CH_4 anomaly**	No data	7-9	**Absence of typical vent fauna**; tetractinellid sponges (genus Cinachyra)
Luso	Basalt	570	**HNO_3-dFe, H_2, CO_2,** CH_4	5.6	62	**Absence of typical vent fauna**; tubicolous amphipods of the families Ischyroceridae and Capprellidae, balonomorph barnacles
D. João Castro	Basalt	20	**CO_2**, H_2S, H_2, CH_4	4-6	27-63	**Absence of typical vent fauna;** amphipods of the family Caprellidae, sponges, hydrozoans and macroalgae

The Luso hydrothermal vent field is a basalt-hosted field system recently discovered at 570 m depth on the slopes of the axial ridge-like seamount Gigante in the MAR, half-way between Pico and Kurchatov fracture zones. Similar to Saldanha vent field, fluid emissions are clear and have low temperature (62 ºC), although venting emanated from chimney structures not present at Saldanha (Figure 3, Table 1). Fluid chemistry is dominated by hydrogen and iron and is moderately acidic. These elements support diverse chemoautotrophic iron and hydrogen-oxidizing microbial communities and benthic fauna dominated by Crustacea. Although no typical hydrothermal vent macrofaunal was found, it is likely that the area of influence vent field is shaping the biological communities living in the background which is characterized by abundant balonomorph barnacles and diverse coral gardens composed by the bubble gum coral *Paragorgia johnsoni* and the soft coral *Anthomastus* cf. *agaricus*. The diffuse fluid emission released by this type of hydrothermal system may represent an important but overlooked source of iron to the oceans, an essential element to primary productivity, thus playing a potentially important role as "fertilizers" of oligotrophic oceanic systems as those in the Azores (Appendix 2).

Dom João de Castro hydrothermal vent field is hosted in a volcanic seamount with the same name located between the islands Terceira and São Miguel on the hyper-slow spreading Terceira Rift (Cardigos et al., 2005). The vents are scattered on the ocean floor and are characterized by the discharge of gases and low-temperature fluids (27-63 ºC) through centimetre-sized orifices in a small area (100 x 50 m) at the 16-45 m depth at the summit of the seamount (Santos et al., 2010). No chimney-like structures are present. The gas composition of the hydrothermal fluids is mainly CO_2 with lesser H_2S, H_2, and CH_4 with a pH of 4-6 (Cardigos et al., 2005). Diverse microorganism communities were found in association with the vents, including bacteria, fungi and thraustochytrid protists, but no typical chemosynthetic hydrothermal vent macrofauna is present (Colaço et al., 2006; Raghukumar et al., 2008). Macrofaunal communities in the close vicinity of the vents are similar to coastal and seamount fauna in the region, with the presence of different species of caprellids (e.g. *Caprella* sp) and the hydrozoans (e.g. *Clytia hemisphaerica*), sponges (e.g. *Cliona viridis*), molluscs (e.g. *Tellina* sp., *Alvania* sp.) and the macroalgae *Codium* spp. and *Sargassum* spp. (Cardigos et al., 2005; Ávila et al., 2004, 2007).

Cold-water coral gardens and reefs, and sponge aggregations

Cold-water corals and sponges are among the most important ecosystem engineers in the Azores, occurring at depths ranging from about 200 to more than 1500 m (Braga-Henriques et al., 2013; Pereira, 2013). They are commonly found where current flow is accelerated often around topographic highs such as seamounts and island slopes (Appendix 1 3.5). The habitats formed by cold-water corals vary from coral reefs, formed mostly by Scleractinia species (stony corals), to dense mono- or multi-species coral aggregations known as coral gardens, where Alcyonacea (gorgonians and soft corals), Pennatulacea (seapens), Antipatharia (black corals) and Stylasteridae (hydrocorals) are the most conspicuous components (OSPAR 2009, 2010a). Sponge aggregations formed species of the classes Demospongiae (demosponges) and Hexactinellida (glass sponges) (OSPAR 2010b) have also recently emerged as important habitats in the Azores, covering extensive areas particularly below 500 m. Coral reefs, gardens and sponge aggregations provide complex three-dimensional structural habitats that support high levels of biodiversity of associated sessile (e.g. zoantharians, anemones, hydroids) and vagile species (e.g. polychaetes, echinoderms, crustaceans, fish) (Buhl-Mortensen et al., 2010; Carreiro-Silva et al., 2011; Braga-Henriques et al., 2011, 2012; Henry et al., 2013; Pham et al., 2015; Carreiro-Silva et al., 2017; Gomes-Pereira et al., 2017).

Over the last decade, extensive scientific research supported by multiple projects (e.g. Hermione, CoralFISH, 2020, ATLAS, SponGES, MapGES) has permitted a better understanding of the ecological importance of deep-sea ecosystems in the Azores. Results of these projects have contributed to the identification of the Azores as a cold-water coral hotspot in the NE Atlantic, with 184 species identified to date comprising species of the anthozoan subclass Octocorallia, orders Antipatharia and Scleractinia and of the hydrozoan family Stylasteridae (Braga-Henriques et al., 2013; Sampaio et al., 2019a). A large proportion of CWCs belongs to Octocorallia with 98 species identified (Sampaio et al., 2019a), representing the highest octocoral diversity given for European waters (Costello et al., 2001). This taxonomic inventory resulted from a combination of historical oceanographic expeditions and other published sources, visits to museum collections as well as from unpublished data from bottom longline by-catch curated at Department of Oceanography and Fisheries – University of the Azores' Marine Biological Reference Collection (COLETA) (Sampaio et al., 2019b). Thus, the list is likely to grow in the future with increasing deep-sea sampling effort from Remotely Operated Vehicles (ROV) expeditions. Over recent years, several new species of Anthozoa have been described for the Azores including one species of black coral (de Matos et al., 2014b) and five species of zoantharia (Carreiro-Silva et al., 2017).

Recently, H2020 ATLAS, SponGES, MapGES and Blue Azores expeditions mapped the deep-sea coral and sponge communities inhabiting previously unexplored areas of the Azores (Friedlander et al., 2019; Morato et al., 2019b). Data from these video surveys together with species distributions models based on coral bycatch data (COLETA database), improved our knowledge of the occurrence and distribution of cold-water coral species and habitats (Morato et al., 2019b). Octocoral dominated coral gardens are commonly found colonizing hard substrates in seamounts. Species composition of these habitats shows a strong bathymetric zonation, with the species *Dentomuricea* aff. *meteor*, *Viminella flagellum*, *Acanthogorgia* spp., *Callogorgia verticillata*, *Paracalyphtrophora josephinae* and *Candidella imbricata* generally dominating coral gardens between 200-600 m depth (Figure 4). Coral gardens formed by the species *Narella bellissima* and *Narella versluysi*, *Pleucorallium johnsonii* and the soft coral *Anthomastus* sp. are commonly found at depths between 600-800 m. In some areas of the MAR, coral gardens formed by century-old *Paragorgia johnsoni* have also been recorded at depths of 500-700m. In deeper waters, bathyal coral fauna such as the bamboo corals *Keratoisis* sp, *Lepidisis* sp. and *Acanella arbuscula* and other octocoral species *Chrysogorgia* sp, *Iridogorgia* cf. *pourtalesii* and *Metallogorgia melanotrichos* forms structuring habitats below 1000m. Extremely long-lived species such as the black coral *Leiopathes* spp. with documented ages of several millennia can also be present on some seamounts

(Carreiro-Silva et al., 2013). The endemic stylasterid species *Errina dabneyi* is also a common element of coral gardens between 300-400 m depth and may form dense assemblages in some seamounts and island slopes.

The reef-building scleractinian corals *Lophelia pertusa* and *Madrepora oculata* are also documented in the region, although they are frequently found as isolated colonies as part of coral gardens while forming reefs in only a few locations, e.g. Menez Gwen hydrothermal vent field (Tempera et al., 2013) and Capelinhos area. Another reef-forming species in the Azores is the scleractinian coral *Eguchipsammia* cf. *cornucopia* (Tempera et al., 2015). Species of this genus were known to form reefs in the Lower Paleocene in many regions of the world but at present are only found forming reefs in the Azores, possibly representing a relic from the geological past.

In the shelf environments between 20-200 m depth, black corals form dense coral gardens, where the most common species are *Antipathella wollastoni*, *Antipathella subpinnata* and *Tanacetipathes* spp. (Tempera et al., 2013; Braga-Henriques et al., 2013; de Matos et al., 2014). Soft corals likely of the genus *Alcyonium* have also been recently documented forming dense coral gardens in small volcanic cones in Capelinhos area.

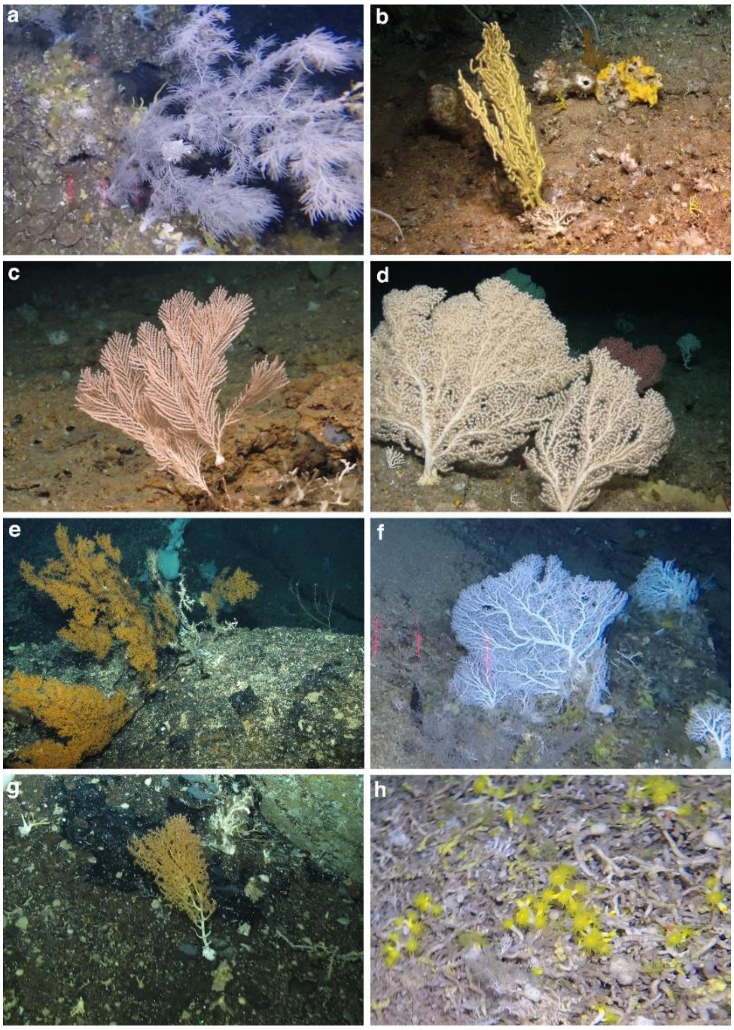


Figure 4. Habitat-forming cold-water coral species in the Azores. (a) black coral *Antipathella subpinnata*; (b) octocoral *Dentomuricea* aff. *meteor*; (c) octocoral *Callogorgia verticillata*; (d) octocoral *Paragorgia johsoni*; (e) black coral *Leiopathes glaberrima*; (f) Stylasterid *Errina dabneyi*; (g) octocoral *Acanella arbuscula* and (h) scleractinian *Eguchipsammia* cf. *cornucopia*. a,d,f,h © Drift camera, IMAR/Okeanos UAç; b,c © ROV Luso/EMEPC / 2018 Oceano Azul Expedition; e,g © Medwaves, ATLAS project.

The habitats formed by deep-sea sponges have been less studied, but recent expeditions have revealed extensive sponge aggregations in the Azorean seamounts. Some of the most important sponge aggregations documented so far are dense and often monospecific aggregations of the glass sponge *Asconema* sp. between 300 and 400m and multispecific aggregations of desmosponges *Leiodermatium lynceus*, cf. *Characella pachastrelloides*, cf. *Neophrissospongia nolitangere*, cf. *Poecillastra compressa*, *Macandrewia azorica*, *Petrosia crassa* and *Phakellia* sp. between 400 and 600 m depth (Figure 5). Aggregations of the glass sponge *Pheronema carpenteri* area also important below 800 m depth.

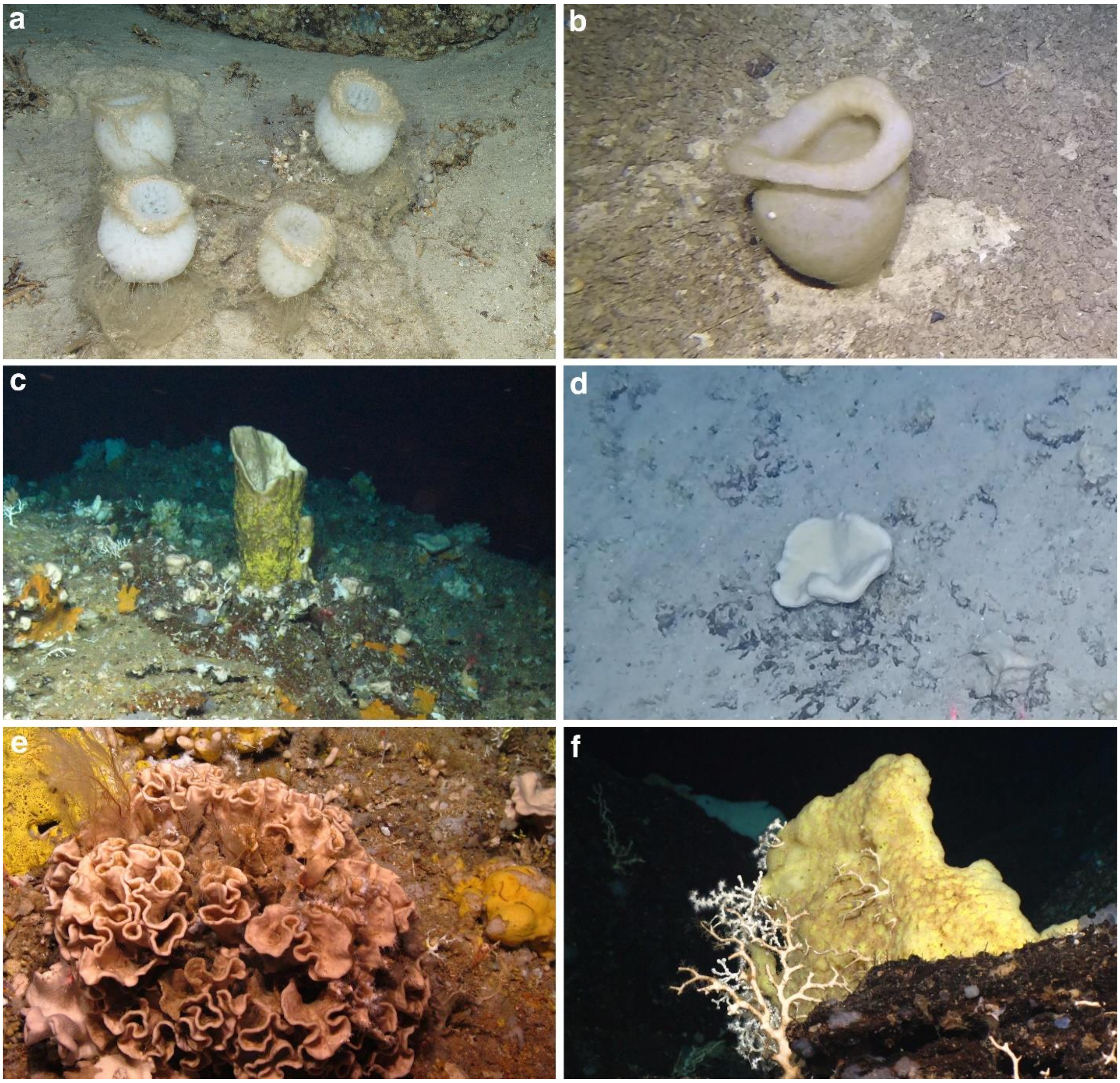


Figure 5. Habitat forming deep-sea sponges in the Azores. Glass sponges (a) *Pheronema carpenteri*; (b) *Asconema* sp.; desmosponges (c) *Characella pachastrelloides*; (d) *Macandrewia azorica*; (e) *Leiodermatium lynceus*; (f) cf. *Poecillastra compressa*. a © Medwaves, ATLAS project; b,c,d © Drift cam, IMAR/Okeanos UAç; e,f © ROV Luso/EMEPC / 2018 Oceano Azul Expedition.

Biogeographic studies indicate that coral species in the Azores show mixed zoographic affinities with a higher affinity to the Lusitanian-Mediterranean biogeographic region (71% shared species) and to a lesser extent to the western North Atlantic (Braga-Henriques et al., 2013). This same trend has also been found for deep demersal fish assemblages (Menezes et al., 2006), likely reflecting higher proximity of the Azores to the eastern continental margin, the past surface currents and glacial events (Chapman et al., 2000). Changes in biogeographic affinities are also observed in-depth, with an increasing proportion of amphi-Atlantic and cosmopolitan CWC and fish species, and a concomitant decrease in low-altitude and increase high latitude species with depth (Menezes et al., 2006; Braga-Henriques et al., 2013), which appears to agree with the expected trend of deeper species occupying significantly larger areas, possibly as a result of more constant environmental conditions (Costello & Chaudhary 2017). This pattern is also consistent with the depth of the permanent thermocline in the NE Atlantic (600–1000 m) and the predominance beneath its lower boundary of deep-water masses formed at high latitudes (i.e. the Subarctic Intermediate Water and the Labrador Sea Water).

Changes in oceanographic conditions through the geological past may also represent an important factor affecting CWC distribution in the Azores, with the biogeographic connectivity with the Mediterranean and NE Atlantic varying during glacial/interglacial periods (Boavida et al., 2019). For example, extensive coral rubble accumulations of reef-building *L. pertusa* and *M. oculata* coupled with rare observations of living reefs, suggests the demise of such coral reefs during the last deglaciation, when environmental conditions (increased temperature and decreased productivity) became unsuitable for *L. pertusa* reef survival (Marina Carreiro-Silva and Norbert Frank, unpublished data). Interglacial periods coupled with geographical isolation might have also led to speciation processes occurring in the Azores, illustrated by some potentially endemic coral fauna such as the stylasterid *Errina dabneyi* and the octocoral *Dentomuricea* aff. *meteor*. It also constitutes refugia for ancient deep-sea fauna, e.g. the living-fossil community' formed by the cyrtocrinid *Cyathidium foresti* and the deep-sea oyster *Neopycnodonte zibrowii*, that survived the Cretaceous/Palaeogene mass extinction (Wisshak et al., 2009).

The distribution, abundance and size of CWCs and sponges has likely been affected by fishing pressure (Appendix 1 5.3). Longline fishing accidental captures as by-catch CWCs with complex 3D morphologies, e.g. octocorals such as *Callogorgia verticillata*, *Paracalypthrophora josephinae*, *Paragorgia jonhsoni* and black coral *Leiopathes* spp. (Sampaio et al., 2012; Pham et al., 2014b, Section 2.2.1), which have high longevity and slow rates and estimated recovery rates of centuries (e.g. Carreiro-Silva et al., 2013). For example, anecdotal reports from fishers suggest a progressive reduction in the accidental capture of *Leiopathes* after 20 years of bottom-longline fishing on insular slopes and seamounts. Large *Leiopathes* colonies (>2 m tall) with estimated ages of >2,000 years, previously collected by fishermen, have not been recorded in recent video surveys in the Azores. This finding could indicate that the largest and oldest colonies have already been removed from the population in heavily fished areas. Selective removal of these large morphologically complex organisms may eventually threaten their population health since growth and recruitment may be outbalanced by the amount removed making population resilience low and recovery highly unlikely.

Vulnerable Marine Ecosystems and VME indicator taxa

Many benthic communities occurring in the Azores, such as hydrothermal vent fields, cold-water reefs and gardens and sponge aggregations may fit the criteria (Section 5.1.5) to define Vulnerable Marine Ecosystems (VMEs), a term coined by Food and Agriculture Organization of the United Nations (FAO) which identifies species, communities, or habitats vulnerable to fishing activity (FAO, 2009). Generally, VMEs have been identified based on the occurrence of indicator taxa such as stony or gorgonian corals, or sponges, with the list of indicators being regularly reviewed by the ICES/NAFO Working Group on Deep-water Ecology (WGDEC)

(ICES, 2019). This list includes organisms that have life-history traits such as slow growth, high longevity, low reproductive potential that makes their recovery from human impacts prolonged (Clark et al., 2016; 2019). Cold-water corals form reefs that can reach 8 000 years, with *L. pertusa* colonies growing linearly at 6–35mm year^{-1} (Roberts et al., 2009). Octocorals and black corals, which dominate benthic assemblages in the Azores, have growth rates of less than 1 cm a year and age spans of hundreds (e.g. bamboo coral *Keratoisis* sp.: Watling et al., 2011) to thousands of years (black coral *Leiopathes* sp. Roark et al., 2009; Carreiro-Silva et al., 2013). This means that if removed from the seabed, these species and the communities they form can take centuries to millennia to recover from human impacts. Although age estimates for sponge species are scarce, studies suggest multi-centennial age spans, e.g. 220 and 440 years (Leys & Lauzon, 1998; Fallon et al., 2010), whereas some sponge reefs are estimated to be up to 9,000 years old (e.g. Krautter et al., 2001). In addition, the three-dimensional structure created by these species provides habitat and serves as important spawning, nursery, breeding and feeding areas for a multitude of fishes and invertebrates (Pham et al., 2015; Gomes-Pereira et al., 2017; Porteiro et al., 2013; Ashford et al., 2019), and provides important ecosystems services such as carbon storage and nutrient remineralization (Thurber et al., 2014).

However, the process of identifying areas that constitute a VME based on indicator taxa is not straightforward as these taxa can occur in varying spatial densities, and the FAO guidelines do not provide threshold values for defining what constitutes ‘‘significant concentrations’’ of VME indicator records that would constitute an actual VME (Auster et al., 2011).

Vulnerable Marine Ecosystems are best identified using high-quality underwater imagery (ROV, towed camera, etc.), allowing an accurate and quantitative description of community composition and associated fauna (e.g. Fabri et al., 2014), and representing bona fide records of VMEs. However, because of high costs associated with surveying large portions of the deep-sea, it is often necessary to use other sources of information such as fisheries bycatch records to identify VME likely areas. As such, IMAR researchers working in the ATLAS project developed and applied a multi-criteria assessment method for identifying VMEs in the North-East Atlantic (Morato et al., 2018; Appendix 1 3.9) and in the whole North Atlantic (Combes et al., 2019). The VME index and the confidence index were applied to the records of the VME database created and curated by the WGDEC. The VME index highlighted areas where a VME is more likely to occur while the associated estimate of confidence indicates how (un)certain that assessment is. The VME index appeared to capture most of the important elements of the VME database, identifying the Azores as an area with high values of VME index. By combining this information with conservation scenarios of current management and human activities, this exercise showed how the VME index could help systematic approaches for large scale MSP when habitat occurrence data is scarce.

Rare and threatened species

The Azores is home for rare and threatened species, including a large diversity of deep-sea fish, sharks and rays and cold-water corals (Braga-Henriques et al., 2013; Das & Afonso, 2017). Given their life-history characteristics and in particular low productivity, many deep-water teleost fish and most deep-water chondrichthyan species are highly vulnerable to fishing impacts, with limited ability to sustain high levels of fishing pressure and slow potential of recover from overfishing (Francis, & Clark, 2005; Kyne & Simpfendorfer, 2007; Devine et al., 2012). The deep-water teleosts orange roughy (*Hoplostethus atlanticus*) and roundnose grenadier (*Coryphaenoides rupestris*) are listed under the IUCN Red List of Threatened Species as Endangered (IUCN Europe 2018). Out of the 25 species of deep-water sharks occurring around the Azores, nearly half are listed under the IUCN Red List of Threatened Species, as Critically Endangered (n=1), Endangered (n=4), or Near Threatened (n=2), or as Data-Deficient (n=7), 2 are not even assessed (IUCN Europe 2018). Some species of deep-sea chondrichthyans occurring in the Azores are very rare. An extreme example is the Azores dogfish (*Scymnodalatias garricki*), a species so rare that it is known only from two prototypes/ specimens caught in the Azores area in 1977 and 2001 at 300 m and 580 m depth respectively (Kukuev, 1988; 2006). Another example is *Rajella pallida* (Pale ray), whose first record for the area between the Charlie-Gibbs Fracture Zone and the Azores was registered in 2004 (Orlov et al., 2006).

Cold-water coral species of Order Antipatharia (e.g. black corals *Leiopathes* spp., *Bathypathes* spp.), Scleractinia (e.g. reef building corals *Lophelia pertusa* and *Madrepora oculata*) and family Stylasteridae (e.g. *Errina* spp., *Stylaster* spp.), are listed under Appendix II of the CITES convention. The black coral *Leiopathes* is particularly vulnerable to impacts because of its extremely slow growth rates and very high longevity (Carreiro-Silva et al., 2013), requiring several centuries for population recovery. The stylasterid *Errina dabneyi* has a very fragile brittle skeleton which makes it partially vulnerable to fishing gear impact and a great proportion of long-line fisheries bycatch (Sampaio et al., 2012). In addition, the communities formed by cold-water corals and sponges including deep-sea sponge aggregations, sea pen communities, coral reefs and coral gardens, as well as oceanic ridges with hydrothermal vents and seamounts that are listed on the OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR, 2009; 2010a,b,c,d).

Deep-water sharks and cold-water corals are common bycatch of deep-water longline fisheries (Machete et al., 2011; Sampaio et al., 2012; Pham et al., 2014b; Fauconnet et al., 2019) and therefore, these species are of particular concern in the Azores.

2.1.4 Role in the Atlantic ecosystem function

The deep-sea benthic ecosystems in the Azores perform several important ecosystem goods and services. Hydrothermal vents are involved in the biogeochemical cycling and elemental transformation of carbon, sulfur, and nitrogen (Lilley et al., 1995; Petersen et al., 2011; Sievert & Vetrini, 2012) and contribute to the enormous diversity of deep-sea organisms and habitats. They use chemical energy from hydrogen, methane, hydrogen sulfide, ammonium or iron to fix inorganic carbon and generate increased microbial and faunal biomass, making them unique ecosystems. The organic matter produced at vents complex with metals like iron or copper released from vents with organic ligands (Bennett et al., 2008; Hoffman et al., 2018), is also spread with the buoyant plume, contributing to the global ocean micronutrient budgets (Tagliabue et al., 2010; Resing et al., 2015). The chemosynthetic productivity from vents is, therefore, exchanged with the nearby deep-sea environments, providing labile organic resources to benthic and pelagic ecosystems that rare otherwise food limited (Levin et al., 2016).

Cold-water coral reefs, gardens and sponge aggregations also support and enhance the highly diverse communities, comprising faunal biomass that is orders of magnitude above that of the surrounding seafloor (Henry & Roberts, 2007; Buhl-Mortensen et al., 2010; Beazley et al., 2013). The three-dimensional structure that they create on the seabed makes them bioengineering species, providing habitat and serving as important spawning, nursery, breeding and feeding areas for a multitude of fishes and invertebrates (Pham et al., 2015; Gomes-Pereira et al., 2017; Porteiro et al., 2013; Ashford et al., 2019).

The ability to construct calcium carbonate frameworks makes deep-water coral reefs unique and provides an important biogeochemical function in the calcium carbonate system (Doney et al., 2009). The structural framework of coral reefs and mounds formed over geological timescales represents carbon reservoirs, contributing to climate regulation (Roberts & Cairns 2014). Octocorals, the main components of coral garden habitats, also have the ability to store carbonate in their skeletal elements contributing to the formation of carbonate sediments and limestone (Matsumoto et al., 2010).

Sponges, with their filter-feeding capacity, are very important as carbon sinks since they can filter more than 90% of bacteria and organic matter from seawater, having an impact not only on the benthic pelagic-coupling of carbon but also on the microbial loop itself (Yahel et al., 2007; Maldonado et al., 2012; Leys et al., 2018). Sponges also have a significant impact on inorganic nutrients cycles, such as silicate, nitrate, nitrite, ammonium and phosphate (Maldonado et al., 2012). Both cold-water coral communities and sponge grounds are important for global biogeochemical cycles and the ocean's benthic-pelagic coupling loop, being responsible for nearly 30% of the coupling between organic matter produced at the ocean surface and the seafloor (Cathalot et al., 2015). They represent hotspots of ecosystem functioning processing substantial amounts of Organic Matter (White et al., 2012; Cathalot et al., 2015) and release nutrients back into the surrounding water (Van Oevelen et al., 2009; Cathalot et al., 2015) that becomes available to associated fauna.

2.2 Pressures impacting the Azores deep-sea

2.2.1 Fisheries

As in most oceanic islands, fishing has always been a key driver of the subsistence and economy of the Azores (Carvalho, 2010). The Azores fisheries are typically characterised as being artisanal and small-scale in nature, with a multi-segmented fleet, targeting multiple species with a wide range of fishing gears and methods (Carvalho, 2010). With the absence of a continental shelf and surrounding great depths, modern fishing occurs around the island slopes and the many seamounts present in its vast exclusive economic zone of 1 million km (Silva & Pinho, 2007; Morato et al., 2008, 2013; Diogo et al., 2015). Dominated by hooks-and-lines, fisheries in the Azores can be categorized as pelagic and deep-sea fishing (Table 2). The pelagic fishing industry is currently composed of: i) a pole-and-line tuna fishery, with an average total catch of about 5,900 $t \cdot year^{-1}$ and its associated livebait fishery with an estimated catch of about 270 $t \cdot year^{-1}$, ii) a pelagic longline fishery targeting swordfish (*Xiphias gladius*), blue shark (*Prionace glauca*), and other pelagic sharks (2,500 $t \cdot year^{-1}$) operated by Azores, mainland Portugal and foreigner fleets; iii) a small purse-seine fishery for small pelagic species targeting mostly blue jack mackerel (*Trachurus picturatus*), and chub mackerel (*Scomber colias*), with an average total catch of 2,100 $t \cdot year^{-1}$ (Table 2; Fauconnet et al., 2019a; Pham et al., 2013). Deep-sea fisheries are currently composed of two main components: i) a bottom longline and handline fishery targeting deep-sea demersal fishes such as blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) or blackbelly rosefish (*Helicolenus dactylopterus*) with an average total catch of 4,300 $t \cdot year^{-1}$, and ii) a drifting deep-water longline fishery for black scabbardfish (*Aphanopus carbo*) that has been in experimental phase since 1998 (Machete et al., 2011), with an average catch of about 125 $t \cdot year^{-1}$ (Fauconnet et al., 2019a).

Other fishing activities in the Azores include recreational fishing, seasonal squid fisheries targeting veined squid (*Loligo forbesi*), and collection of coastal marine invertebrates such as octopus (*Octopus vulgaris*), limpets or slipper lobster (S*cyllarides latus*) (Morato, 2012; Pham et al., 2013). In recent years there has been an increase in the interest for collecting algae.

Table 2 Average annual catch and discards, with 95% confidence interval (CI), and weighted annual discarded fraction (%) by fishery over the 2000–2014 period (Fauconnet et al., 2019a).

Fishery	Main target	Average Catch (t)	CI	Average Discard (t)	CI	Discards (%)
Pole-and-line	Tunas	5902	[4014.8 - 7789.9]	2	[1.3 - 2.6]	0.03
Tuna live bait fishery	Small pelagics	272	[223.6 - 320.8]	30.5	[24.2 - 36.7]	11.19
Bottom longline and handline	Deep-sea demersal fishes	4336	[4043.7 - 4629.2]	447.3	[354.7 - 539.9]	10.32
Purse-seine	Small pelagics	2087	[1827.2 - 2347.6]	270.5	[220.4 - 320.5]	12.96
Pelagic longlines – foreign fleet	Swordfish and pelagic sharks	1156	[1015.4 - 1297.5]	25	[23.4 - 26.5]	2.16
Pelagic longline – mainland fleet	Swordfish and pelagic sharks	816	[564.1 - 1068.8]	20.6	[14.2 - 27]	2.52
Pelagic longline – regional fleet	Swordfish and pelagic sharks	565	[415.7 - 715.3]	246.3	[183.6 - 309]	43.55
Recreational fishing	Diverse species	540	[471.2 - 609.9]	24.6	[20.8 - 28.4]	4.56
Handline jig	Squids (*Loligo forbesii*)	404	[300.1 - 509.2]	0	[NA - NA]	0
Collection of invertebrates	Coastal invertebrates	236	[211 - 261.1]	0	[NA - NA]	0
Drifting deep-water longline	Black scabbardfish	125	[40.4 - 210.7]	2.5	[0.8 - 4.2]	2.01

The deep-sea bottom longline and handline fishery

Fishing techniques

Many different types of longlines and handlines are used in the Azores (Figure 6). The bottom longline and handline fishery include a broad range of fishing techniques from horizontal bottom longline rock/buoy technique with thousands of hooks to vertical longlines (*gorazeira*) to handlines with only hundreds of hooks. One of the most common longline gear used in the commercial demersal fishery in the Azores has both a stone/buoy or stone/stone configuration (Menezes, 2003). The longlines are usually set from four-sided skates, with about 30 size n 9 hooks (i.e. the legal size corresponding to 12 mm gape width) by quarter-skate side, of approximately 36.5 m long. On average, 12 skates gear length covers approximately one nautical mile (Menezes, 2003). The bait used is mostly chopped salted sardine or mackerel (Morato, 2012). The fishing gears are deployed at depths up to 1200 m, with a mode between 200–600 m where the most important commercial species occur (Menezes, 1996).

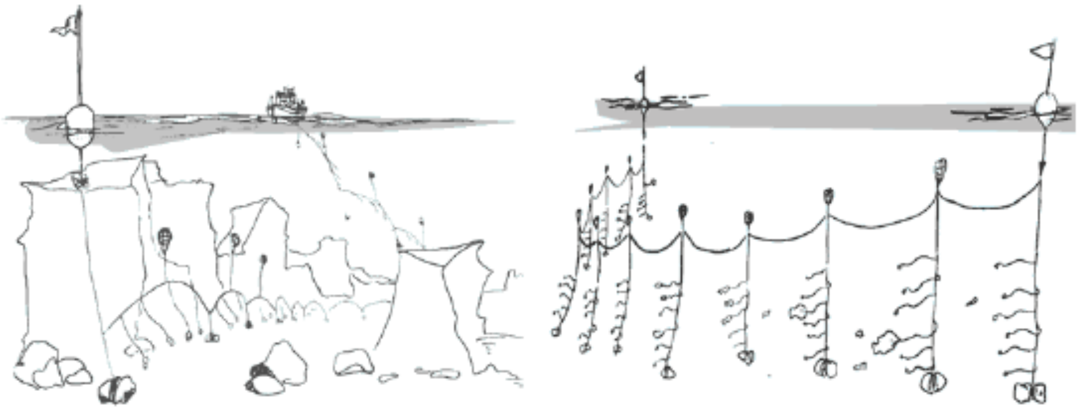


Figure 6. Drawing exemplifying the bottom longline fishing techniques for demersal species in the Azores. Source: downloaded in 2012 from http://www.pescas.net/artespescas.php.

The fishery operates all year long, but the fishing effort is usually higher in the summer (Figure 7). The artisanal fleets operate mainly during the summer months, with fishing trips lasting for a day or week at the most, and deploying up to 1,500 hooks per set. The large-scale fleet operates all year round, with fishing trips lasting up to a month and deploying on average 2,500 hooks per set (Carvalho, 2010; Morato, 2012).

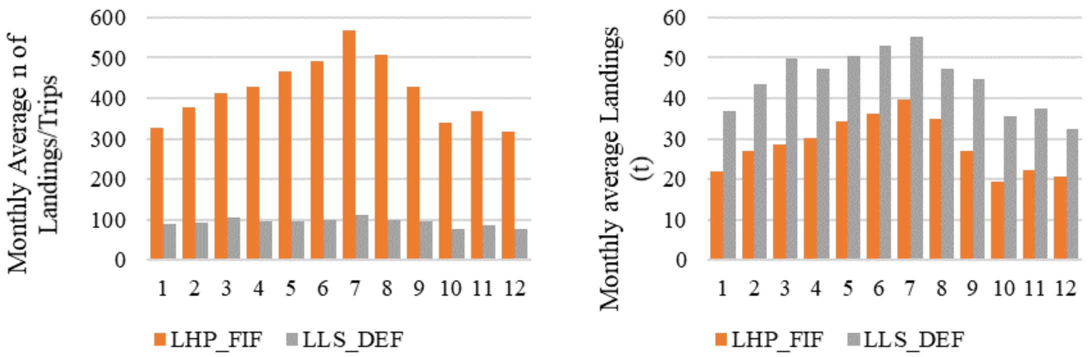


Figure 7. Average number of landing events/trips (left) and landing volumes (right) by month over the period 2002-2018 for handliners (LHP_FIF) and bottom longliners (LLS_DEF).

Fishing fleet

Over the period 2010-2018, an average of 370 vessels were registered in the bottom longline and handline fishery, representing 47% of the total number of fishing vessels registered in the Azores over this period (https://srea.azores.gov.pt/). Out of those 370 vessels, 84% (310 vessels) declared their catch originated from handlining, while 16% (61 vessels) declared their catch originated from bottom longlines. The bottom longline and handline fisheries are predominantly small-scale with >89% of fishing vessels smaller than 12m length, most of which being open-deck wooden boats (Figure 8). The proportion of small boats is higher for vessels deploying handlines (with >94% of fishing vessels <12m length) when compared to longliners (Figure 8). In recent years, the number of bottom longliners has decreased while the handliners remained approximately constant (Figure 8). The incentive to this conversion may lie in need to reduce cost but also in differences in fishing rights between both gears in the coastal areas. Indeed, bottom longliners are currently forbidden to fish in coastal areas and island slopes, in most areas up to 6 nm from shore, while this limitation is only set to 1 nm from the coast for most handliners. Due to those limitations and the absence of continental shelf, the bottom longline fishery is at present mostly an offshore seamount fishery (Morato, 2012; Diogo et al., 2015).

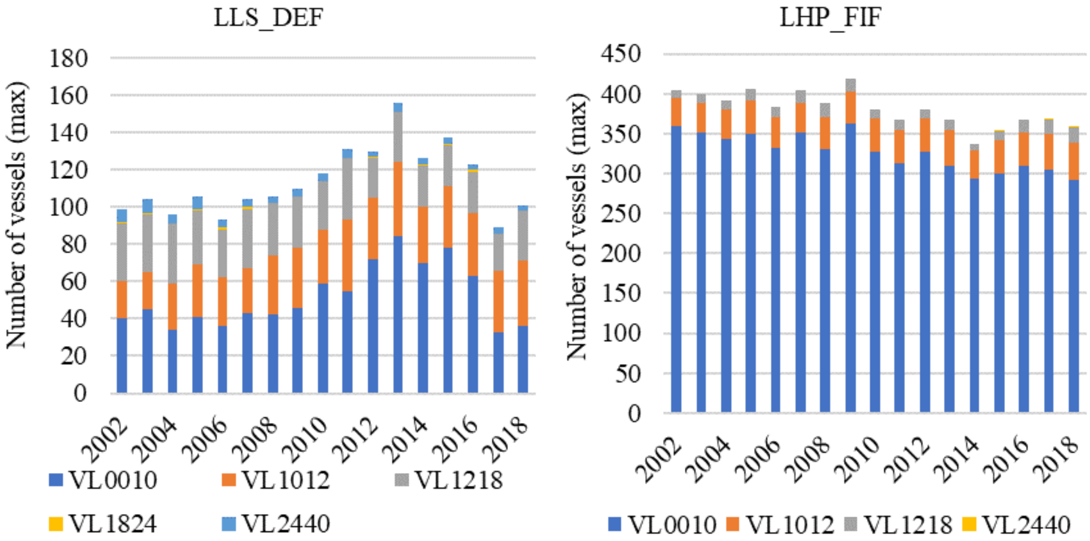


Figure 8. Maximum annual number of fishing vessels declaring landings using bottom longlines (LLS_DEF; left) and handlines (LHP_FIF; right) by vessel size categories (VL0010 = vessels inferior to 10m long; VL1012 between 10 and 12m long; VL1218 between 12 and 18m long, VL1824 between 18 and 24m long; VL2440 over 24m long) based on official landing statistics.

Fish species and yields

The total catch (including landings, unreported catch and discards) of the bottom longline and handline fishery was estimated to average 4,500 t·year^{-1} over the period 2008-2017, of which discards were estimated to represent 11.0%, i.e. 510 t·year^{-1} (Figure 9), Fauconnet et al., 2019a; Savina-Rolland, et al. 2019). Landings from bottom longlines represented 68% of the total landed volume for this fishery, i.e. 2,100 t·year^{-1}, over the period 2010-2018, while landings from handlines averaged 960 t·year^{-1} (Figure 9). Discarded fractions are usually higher for bottom longlines than for handlines representing, respectively, 20.03% and 12.65% of the total catch measured in number of individuals (Figure 9). Information on the reasons for discarding revealed that undersize was the main reason for discards in both gears (Figure 10). Undersized fish included individuals with low commercial value due to their small sizes, and individuals below the Minimum Landing Size (MLS). Existing regulations were identified as the predominant reason for discarding in this fishery, with the increase in discarding coinciding with the implementation of the Total Allowable Catch (TAC) system (Pham et al., 2013; Fauconnet et al., 2019a) and increased MLS. Despite this fishery catching a wide diversity of fish species.

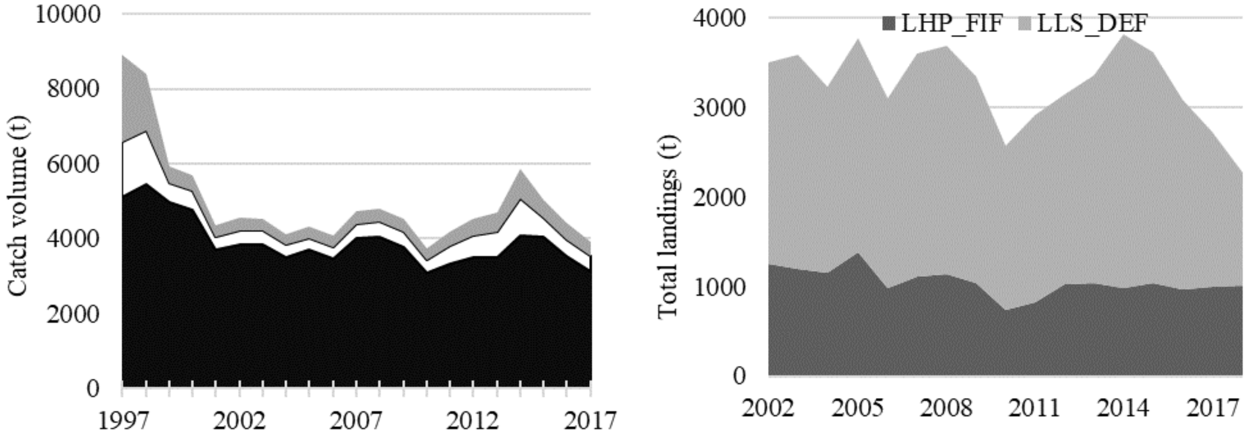


Figure 9. Left; Time series of catch volume of the bottom longline and handline fishery, segregated between reported catch (i.e. official landings; in black), unreported discards (white) and unreported catch for other uses (including bait; in grey) (Fauconnet et al., 2019a; Savina-Rolland et al., 2019). Right; landed volumes segregated between handlines (LHP_FIF) and bottom longlines (LLS_DEF) based on official landings statistics.

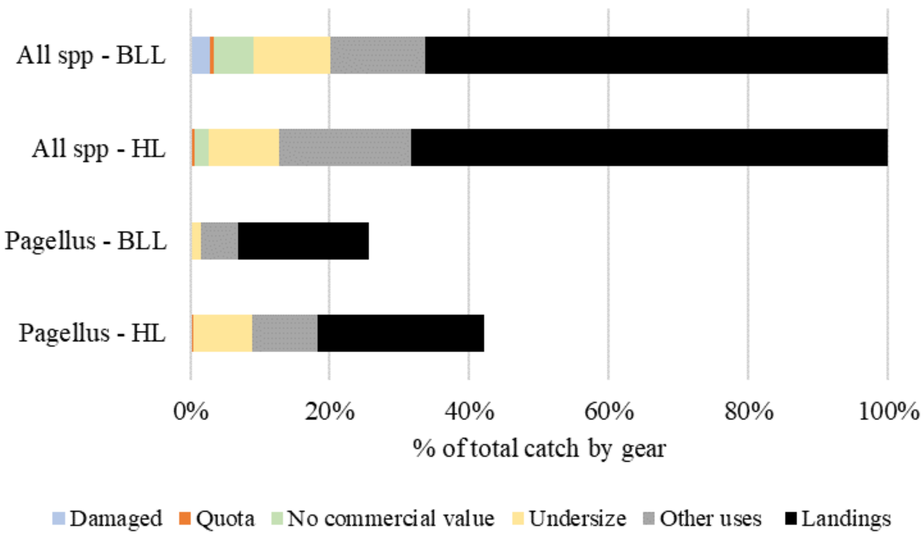


Figure 10. Distribution of the fate of the total catch in number of individuals for bottom longline (BLL) and handline (HL). "Damaged", "Quota", "No commercial value" and "Undersize" are reasons for discarding, based on data from observer programmes collected over the period 2010 – 2017. For all species together (All spp) and for blackspot seabream (*Pagellus bogaraveo*) only.

The main target species of the bottom longline and handline fishery, and first species in landed value in the Azores, is the blackspot seabream *Pagellus bogaraveo,* with 550 t·year^{-1} landed (average 2000-2014). Yet, the total catch of this fishery includes more than 20 species of commercial importance in the Azores, including: European conger (*Conger conger*; 250 t·year^{-1}), wreckfish (*Polyprion americanus;* 180 t·year^{-1}), blackbelly rosefish (*Helicolenus dactylopterus;* 140 t·year^{-1}), forkbeard (*Phycis phycis;* 100 t·year^{-1}), alfonsinos (*Beryx splendens*; 42 t·year^{-1}, and *B. decadactylus;* 12 t·year^{-1}), red porgy (*Pagrus pagrus;* 52 t·year^{-1}), offshore rockfish (*Pontinus kuhlii;* 24 t·year^{-1}). Species with high discard amounts included the silver scabbardfish

(*Lepidopus caudatus*), European conger and blackbelly rosefish due to MLS and the low economic value of small individuals, and alfonsinos, especially in years when the TAC was exceeded.

Marked differences in catch compositions exist between handliners and longliners. Catch diversity is higher with bottom longlines (>100 species) than with handlines (around 40 species). With handlines, the catch is largely dominated by blackspot seabream (42.2%), while with bottom longlines, blackspot seabream is also among the species caught in largest proportions (25.7%) but the catch is more widely distributed among species. Catch weights of handliners are lower than those of longliners.

Table 3. Species contributing to over 1% of the total catch of the bottom longline and handline fishery (* = quota, º = TAC 0, ^ = MLS), with contribution to the total catch weight of the fishery, annual discard weight estimate and 95% confidence intervals (CI) in tonnes, and discarded weight fraction, for the 2000–2014 period (Fauconnet et al., 2019a).

Species	Common name	% of total catch	Discard w. (t·year^{-1})	CI	Discarded fraction (%)
*^*Pagellus bogaraveo*	Blackspot seabream	22.64	21.3	[13.83 - 28.69]	2.17
^*Conger conger*	European conger	12.00	68.9	[50.92 - 87.98]	13.25
Polyprion americanus	Wreckfish	7.16	0.8	[0.17 - 1.45]	0.26
Lepidopus caudatus	Silver scabbardfish	7.12	104.5	[34.93 - 179.99]	33.82
^*Helicolenus dactylopterus*	Blackbelly rosefish	6.92	32.7	[19.71 - 45.45]	10.88
Phycis phycis	Forkbeard	5.78	13.7	[7.72 - 19.8]	5.45
*^*Beryx splendens*	Splendid alfonsino	4.81	22.0	[16.86 - 26.83]	10.55
Raja clavata	Thornback ray	2.53	24.6	[7.76 - 41.83]	22.44
^*Pagrus pagrus*	Common seabream	2.10	1.1	[0.65 - 1.6]	1.23
º*Centrophorus squamosus*	Leafscale gulper shark	1.92	17.8	[8.76 - 47.68]	21.43
Mora moro	Common mora	1.72	3.5	[0.73 - 6.32]	4.72
Serranus atricauda	Blacktail comber	1.67	0.1	[0.04 - 0.19]	0.17
Galeorhinus galeus	Tope shark	1.50	4.3	[0.01 - 8.53]	6.58
Pontinus kuhlii	Offshore rockfish	1.41	2.1	[1.07 - 3.1]	3.42
Muraena helena	Mediterranean moray	1.21	7.6	[2.66 - 12.65]	14.57
**Aphanopus carbo*	Black scabbardfish	1.04	4.3	[2.17 - 11.37]	9.56
Others	Others	18.47	118.0	[63.48 - 177.43]	14.73

Under the European Common Fisheries Policy, landing obligation regulation, discards of quota species have to be landed, and counted against the quota (Reg. EU 1380/2013), raising concerns on the implications it could have on the bottom longline and handline fishery in the Azores (Fauconnet et al., 2019b). Yet, for the main quota species caught exemptions were granted. For blackspot seabream caught in the region (ICES subarea X) with hooks and lines, a high survival exemption was granted in 2018 (Reg. EU 2018/2033). Scientific evidence presented to the EU Scientific, Technical and Economic Committee for Fisheries (STECF) to support this exemption (STECF, 2018) included: i) results from onboard observers' data showing a 76% and 73% vigorous vitality status for blackspot seabreams caught with deep-water bottom longline and handlines respectively (Figure 11); and ii) results from an acoustic and satellite telemetry tagging programme (in place since 2001) showing a 67% survival, 8 days after capture, directly demonstrating high survival rate of fish discarded carefully under experimental conditions. For alfonsinos (*Beryx* spp.) caught in the region (ICES sub-area X) by hooks and lines, a 5% *de minimis* exemption was granted in 2018 (Reg. EU 2018/2033). Arguments presented to support the *de minimis* request included difficulties in further increasing selectivity because longline fishing is already very selective, and socio-economic issues mainly relating to the fact that this fishery operates in one of the outermost regions, where the economy is based on the activity of this fleet and where there are distance and market obstacles to overcome (STECF, 2018). Further, it was shown that avoidance measures of alfonsinos are already used in the region, including technical and tactical strategies that contributed to a decrease in the catch of alfonsinos.

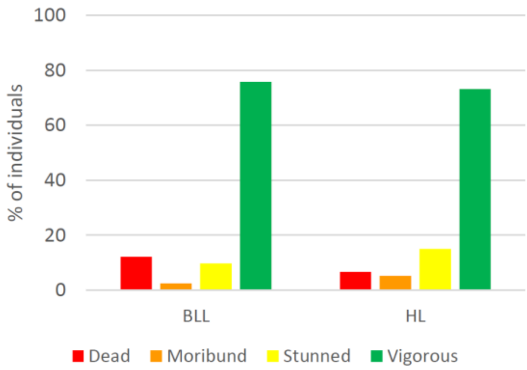


Figure 11. Vitality status of the blackspot seabream sampled after capture with deep-water bottom longlines (BLL) and handlines (HL) in the Azores (Savina-Rolland et al., 2019).

Stock status

Most target species of the bottom longline and handline fishery are deep-water species, and thus their stock status is assessed by the ICES Working Group on the Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP). Longline surveys have been conducted annually during spring, covering the main areas of distribution of demersal species (the coast of the islands, and the main fishing banks and seamounts), with the primary objective of estimating fish abundance for stock assessment (Pinho, 2003).

The Azorean bottom longline survey has been used to provide proxies for relative abundance estimates of *Pagellus bogaraveo*, since the survey design is adapted to the stock behaviour covering most of the species habitat (with the exception of seamounts around the Mid-Atlantic Ridge) (ICES, 2015, 2019). Results from the exploratory analyses seem to be in agreement, suggesting that the stock has been explored at or above the Maximum Sustainable Yield (MSY) level. The exploitable spawning biomass was estimated at about 12% of the virgin level, and the total exploitable biomass estimated by the model at the current fishing mortality was about 33% (ICES, 2017). In 2017, the Surplus Production in Continuous-Time model (SPICT) was explored using all available information from the Azorean bottom longline survey from 1995 to 2016 and commercial fishery, landings for the period 1985–2016, and nominal CPUE for the period 1990–2016 (ICES, 2017). The model suggested the resource is overexploited (being explored unsustainable almost during all the time-series) and will be depleted under the current exploitation pattern. However, it was advised to interpret those results with care, particularly due to the fact that this is a sex change stock, which was not fully encompassed by the model (ICES, 2017). In the absence of analytical stock assessment, the precautionary approach is currently applied to the management of this stock, and it was advised that TACs should be consistent with catches in recent years (ICES, 2017, 2019). Further concerns raised from the exploitation of juvenile blackspot seabreams by different fisheries around the Azores (Pinho et al., 2014). Even if several measures were implemented recently to protect juveniles, it is believed that a decrease in fishing effort would be necessary to achieve the sustainability of the stock (Pinho et al., 2014).

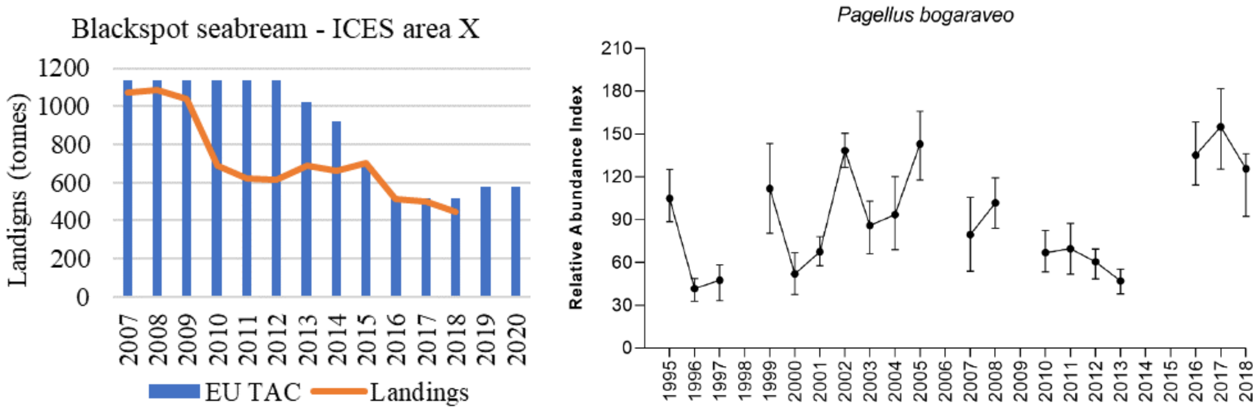


Figure 12. Total landings of blackspot seabream in the Azores with annual EU TAC (in tonnes) set for the stock (left), and annual abundance in number (Relative Population Number) of *Pagellus bogaraveo* from surveys for the period 1995-2018 (ICES Azores 10.a.2; right) (ICES, 2019).

Abundance indices from the Azores longline survey are also available for alfonsinos (Figure 13) (ICES, 2019). Yet, the WGDEEP working group expressed concerns on the reliability of these indices as an indicator of North East Atlantic abundance index due to the relatively small numbers of individuals caught each year, particularly for *B. decadactylus*. It was argued that the surveys are not well designed for assessing these highly mobile and aggregative species particularly for *B. decadactylus*. Therefore, the working group concluded it was more appropriate to base advice on catch history (ICES, 2019). In the absence of analytical stock assessment, the precautionary approach is currently applied to the management of this stock (Santos et al., 2019a). Yet, it is considered that, as a consequence of their spatial distribution associated with seamounts, their life history and their aggregating behaviour, alfonsinos can only sustain low rates of exploitation, and fisheries on such species should not be allowed to expand above current levels unless it can be demonstrated that such expansion is sustainable, the exploitation of new seamounts should not be allowed either (ICES, 2019).

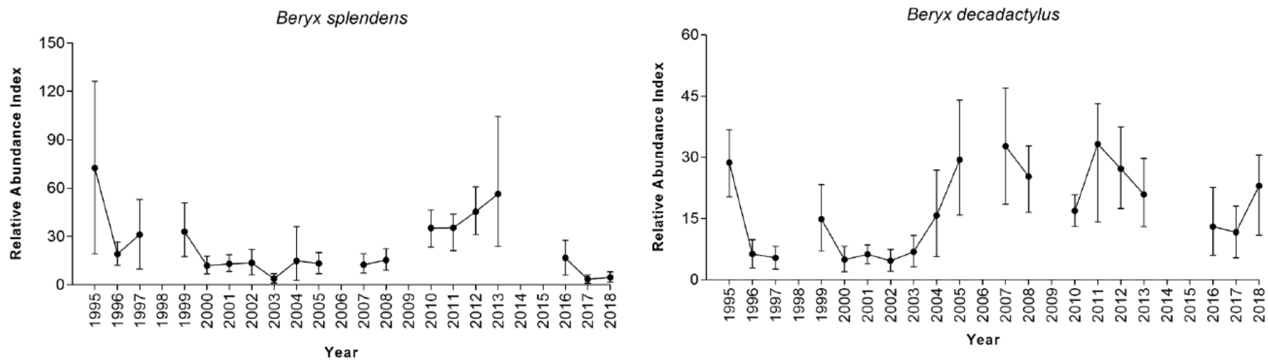


Figure 13. Annual bottom longline survey abundance index in number available for the splendid alfonsinos (*Beryx splendens*; left) and golden eye perch (*B. decadactylus*; right) from the Azorean deep-water species surveys (ICES Subarea 10a2) (ICES, 2019).

The bottom longline and handline fishery is the most important fishery in terms of landed value, with an average value of 18.3 M€ per year over the period 2010-2018, representing 57% of the total landed value in the Azores (Figure 14). While in terms of landed volume, it only accounts for 37% of the total landed volume in the Azores, with an average of 3670 tonnes per year (SREA, http://estatistica.azores.gov.pt, 2019).

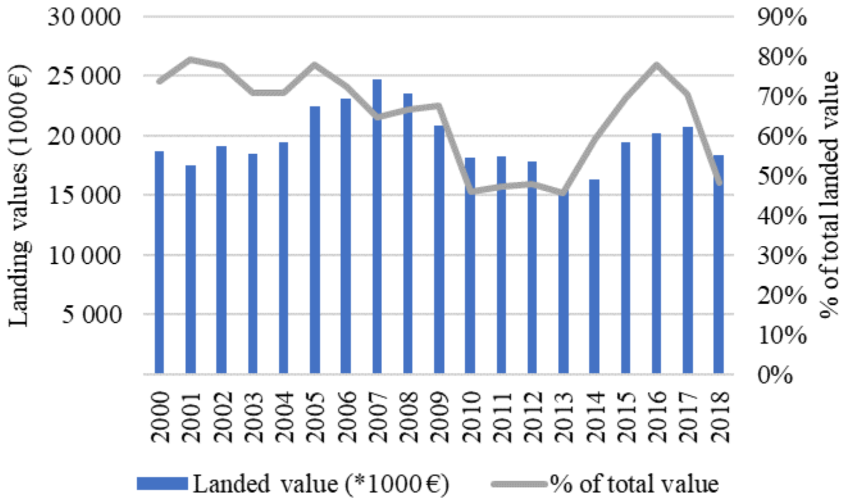


Figure 14. Landing values (in thousands of €) of the bottom longline and handline fishery declared in the Azores over the period 2000-2018, and percentage of the total value landed by all Azorean fisheries. Source: SREA, http://estatistica.azores.gov.pt, 2019.

The last assessment of the number of fishers employed in this fishery was undertaken in 2005 and estimated that the bottom longline fisheries directly employed in 2005 about 350 crew members while the handline fishing employed about 930 fishers, representing about 60% of all professional fishermen in the Azores (Carvalho et al., 2011). Since 2005, the total number of fishers (i.e. all fisheries confounded) increased until 2017 but sharply decreased in 2018 (Figure 15; SREA, http://estatistica.azores.gov.pt, 2019).

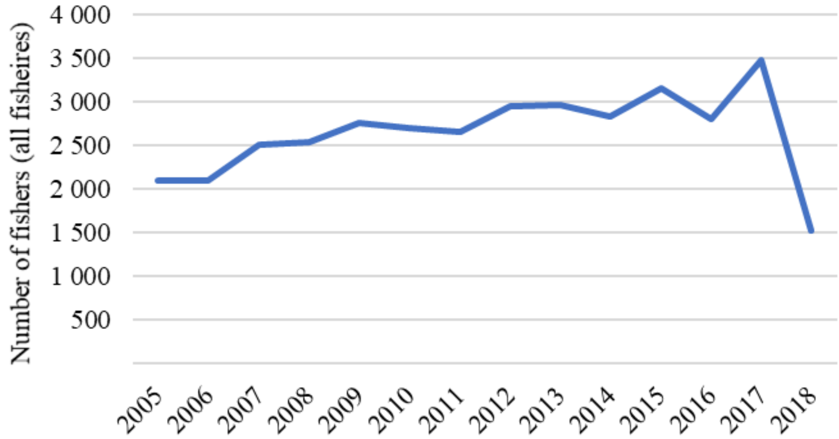


Figure 15. Total number of fishers registered in the Azores, all fisheries confounded (SREA, http://estatistica.azores.gov.pt, 2019).

Interviews with bottom longline and handline fisher's suggested that the recent trend of gear conversion from bottom longlines to handlines is expected to have some socio-economic consequences (Fauconnet et al., 2019b). Handlining was perceived as more cost-effective, with higher selling prices due to better fish condition and larger individuals, reduced expenses (in employment/crew, bait, number of hooks, fuel) and increased flexibility in fishing tactics and techniques, largely compensating lower catches (Fauconnet et al., 2019b). From a social perspective though, this conversion likely has detrimental effects on employment as the number of crew members needed by handliners is much lower than by longliners, including crew members on board, but also inland crew (including many women) that are hired by longliners to prepare/bait the gear (Fauconnet et al., 2019b).

Bycatch of sensitive species

Bycatch from the bottom longline fishery is of concern because they include many deep-water sharks listed in the IUCN Red List of endangered species (Table 4). According to the European IUCN Red List Assessment 2018, these include the "critically endangered" gulper shark (*Centrophorus granulosus*), blue skate (*Dipturus batis*), the "endangered" kitefin shark (*Dalatias licha*), Portuguese dogfish (*Centroscymnus coelolepis*), leafscale gulper shark (*Centrophorus squamosus*), and birdbeak dogfish (*Deania calcea*); the "near threatened" greenland shark (*Somniosus microcephalus*), and the "least concern" longnose velvet dogfish (*Centroscymnus crepidater*).

Table 4. Bycatch from the bottom longline fishery of deep-water species for which TAC is 0 or fishing is prohibited under EU regulations, with annual catch weights in tonnes per year (and 95% Confidence Intervals) by species, percentage of the species catch within the total catch of the fishery, and percentage of occurrences (i.e. ratio number of sampled fishing operations (FOs) where the species was caught to the total number of sampled FOs). Source: Fauconnet et al., 2019a.

Species	Discard $t \cdot year^{-1}$	CI discard	Catch $t \cdot year^{-1}$	CI catch	% total catch	Occurrence
Centrophorus squamosus	17.84	[8.76 - 47.68]	83.26	[40.89 - 222.5]	1.912	0.6
Dalatias licha	4.22	[2.41 - 5.78]	37.80	[26.14 - 47.83]	0.868	14.63
Centrophorus granulosus	0.41	[0.08 - 0.69]	36.47	[8.24 - 60.76]	0.838	4.01
Deania profundorum	8.84	[6.4 - 16.85]	19.89	[14.51 - 37.58]	0.457	9.82
Hexanchus griseus	6.39	[0.73 - 11.27]	14.41	[2.5 - 24.66]	0.331	1.3
Etmopterus spinax	13.35	[9.47 - 16.7]	13.35	[9.47 - 16.7]	0.307	30.46
Deania calcea	3.53	[0.83 - 5.84]	7.21	[2.04 - 11.65]	0.166	6.81
Etmopterus pusillus	2.87	[1.13 - 4.37]	2.87	[1.13 - 4.37]	0.066	26.95
Heptranchias perlo	0.00		0.15	[0.15 - 0.15]	0.003	0
Centroscymnus owstonii	0.00		0.11	[0.11 - 0.11]	0.002	0
Hoplostethus atlanticus	0.08	[0.05 - 0.1]	0.09	[0.07 - 0.12]	0.002	4.91

Despite the fishing prohibition of several species of deep-water sharks set in European fisheries regulations since 2010, occasional bycatch of least ten different species still accounted for 8% of the discards of the bottom longline and handline fishery in the recent years (2010-2014) (Fauconnet et al., 2019a). Yet, handliners had much smaller bycatch of deep-water sharks than bottom longliners. This difference is mostly due to handlines operating shallower, with lighter tackle line more prone to break or to be cut by the sharks, and reduced number of hooks (Fauconnet et al., 2019b). Deep-water sharks caught with handlines are also more likely to survive after release. As for fishing interactions with cetaceans, Silva et al. (2011) found that cetaceans were recorded in the vicinity of the longline gear in 5% of all the sets monitored. Cetaceans were responsible for damaging the fish caught in less than 1% of the longline sets, but no cetaceans were captured in any of the observed longline sets (Silva et al., 2011).

Effect of fisheries on natural habitats

In the last decades, the human pressure on deep-sea ecosystems has sharply increased, threatening their health, biodiversity and resilience. For example, global landings of marine fishes have shifted to deeper water species over the last 60 years (Morato et al., 2006; Watson & Morato, 2013), suggesting deep-sea fisheries are exploiting the last refuges for commercial fish species. Pham et al. (2014b) found that deep-sea bottom longline fishing has reduced impact on vulnerable marine ecosystems when compared to bottom trawling. They found reduced bycatch of cold-water corals and limited additional damage to benthic communities, especially compared with bottom trawls (Figure 16). Bycatch of cold-water corals was registered in 44.7% of the longline sets, but with a very small average number of organisms (Pham et al., 2014b). Longlines were found to mostly (91% of the bycatch) impact large organisms with a complex morphology, which is of particular concern because these are generally long-lived species with very slow growth rates (e.g. *Leiopathes* sp.). The most abundant species composing the primary bycatch were the antipatharian, *Leiopathes* spp., the stylasterid, *Errina dabneyi* and the gorgonians, *Callogorgia verticillata, Acanthogorgia armata*, *Paracalyptrophora josephinae* and *Viminella flagellum* (Sampaio et al., 2012). Most of these species are important habitat builders in the region. In total, thirty-nine different taxa of anthozoans and hydrozoans were recorded from longline bycatch, representing 26% of currently known cold-water corals (Sampaio et al., 2012). To provide insights on the level of longline damage not accounted as bycatch, the physical conditions of benthic communities on a fishing ground were also assessed by Pham et al. (2014b). From the colonies observed close to lost fishing lines, 63% were found intact, 15% with minor damage, 20% with major structural damage but with potential for survival, and only 3% of the cold-water corals were found in a critical status with no survival potential. Additionally, marine litter has been found in the deep-waters of the Azores highlighting the extent of the litter problem and the need for action to prevent the increasing accumulation of litter in marine environments (Pham et al., 2014a). Lost fishing gear was the most common marine litter item in the Condor seamounts, often found entangled on dominant octocorals, indicating a substantial indirect effect of fishing on deep-sea habitats (Pham et al., 2013).

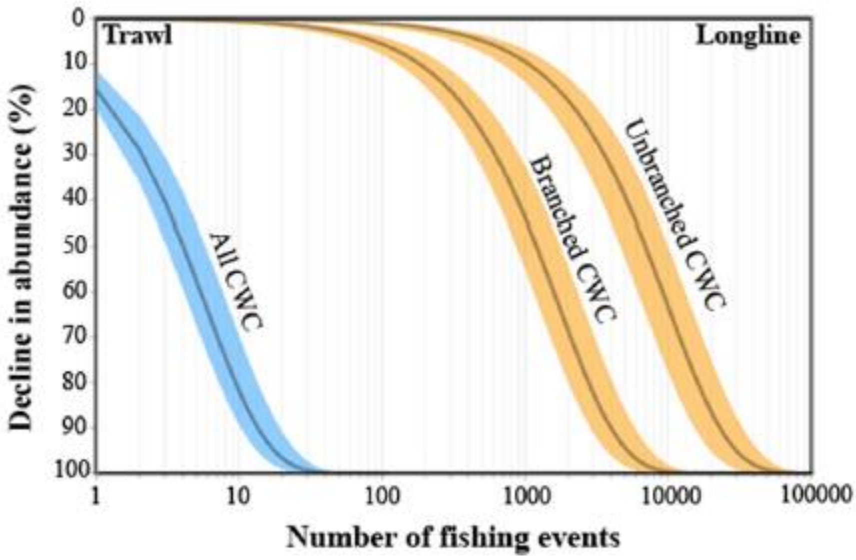


Figure 16. Cumulative impact of deep-sea bottom trawl and longline on cold-water corals (Pham et al., 2014).

Deep-water drifting longline

Fishing techniques

Drifting deep-water longline usually consists of a mainline connected to several perpendicular vertical lines (free lines) generally 900m (±100m) long with a buoy attached to the upper end (Figure 17). The mainline drifts above the bottom fishing at different distances from the seabed which ranges from 1000 to 1900 m depth. Mustad hooks number 5 are usually used connected to the mainline through 3.5 m length leaders (or gangions). The average number of hooks per set in the Azores is 3600, while the mean soak time is 10 hours (Morato, 2012).

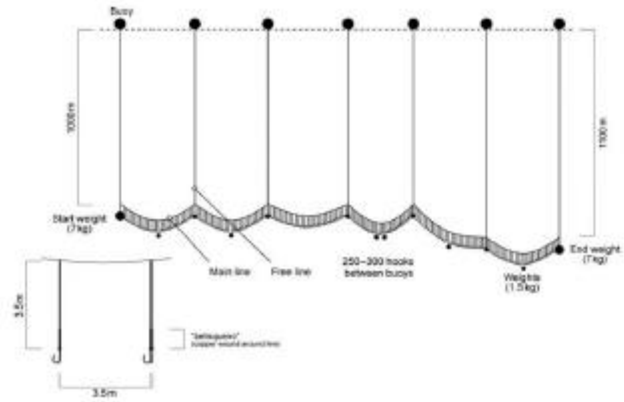


Figure 17. Sketch of the longline fishing gear used in the black scabbardfish experimental fishery in the Azores. (adapted from Machete et al., 2011).

Fishing fleet

The drifting deep-water longline fishery targeting black scabbardfish was experimented in the Azores in 1998. Nowadays, it is still considered an experimental deep-water fishery in the Azores. According to a report prepared by Ramos et al. (2013), in 2010 there might have been about 10 fishing vessels with a mean length of 14m operating the drifting deep-water longline in the Azores. However, technical and market difficulties have limited the development of this fishery (Machete et al., 2011), and this number has likely diminished since then (Morato, 2012). In 2017, only a few vessels registered in Madeira island operated inside the Azores EEZ. No fishing vessels were involved in this fishery in 2018 or 2019.

Fish species and yields

The activity and resulting catch of this fishery, have fluctuated considerably in the Azores. In the last 20 years, the landings were small (130 t per year on average) with a peak at 450 t in 2012 (Figure 18). The catch is by far dominated by black scabbardfish, which contributes to 82.6% of the total catch weight (Fauconnet et al., 2019a), while bycatch species accounted for about 17.4% of the total catch. In the Azores as in other regions, deep-sea sharks composed the main bycatch (Machete et al., 2011), mainly leafscale gulper shark and the Portuguese dogfish. Other species reported as bycatch of this fishery but with low numbers include *Etmopterus* sp., *Mora moro*, *Deania* cf. *calcea*, *Centroscymnus crepidater*, *Alepochepalus rostratus*, *Deania profundorum* and *Chiasmodon niger*. There is a growing concern with the bycatch of some of these species, and Machete et al. (2011) suggested that those catches should be closely monitored in the future if the fishery is to be expanded in the Azores, which has not happened yet. Discards were estimated to represent 2.5 t per year, i.e. 2.0% of the total catch of the fishery (Figure 18).

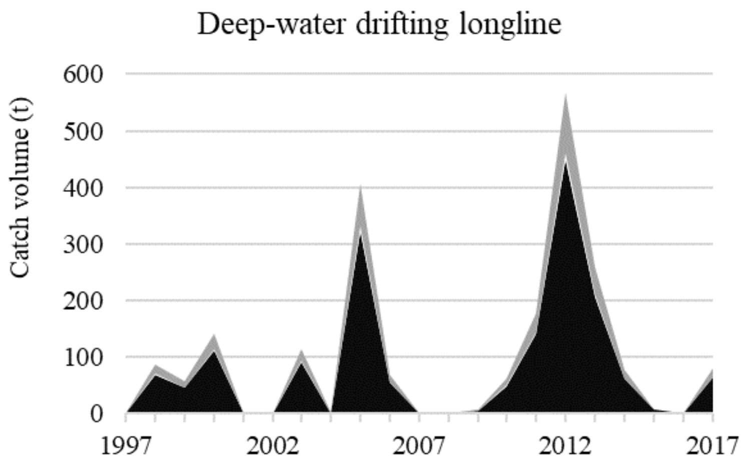


Figure 18. Time series of catch volume of the deep-water drifting longline fishery, segregated between reported catch (i.e. official landings; in black), unreported discards (white) and unreported catch for other uses (including bait; in grey). Catch of Madeira registered vessels fishing inside the Azores EEZ were not accounted in the unreported catch yet. Source: Savina-Rolland et al., 2019.

Stock status

Most of the Azores EEZ lies in ICES Division X where the TAC for black scabbardfish has been approved in conjunction with areas VIII and IX. The stock structure in the whole Northeast Atlantic remains uncertain, despite the fact that all available information supports the assumption of a single stock from Faroese waters and the west of the British Isles down to Portugal (Farias et al., 2013). The links with other areas such as the Azores (ICES Division X) is less clear, as in this division two different species *A. carbo* and *A. intermedius* coexist (Besugo et al., 2014). Despite the variability on the overall landings along the years, available data suggest that ICES Division X is an area of major concentration of the species, consistently with the current perception on the spatial distribution of the species in the Northeast Atlantic (ICES, 2019). However, the co-occurrence of two different species, *A. carbo* and *A. intermedius*, in ICES Division X (Besugo et al., 2014) needs to be, in the future, taken into consideration to provide advice for this stock (ICES, 2019). In the absence of analytical stock assessment, the precautionary approach is currently applied to the management of this stock.

In the Azores, the stock status of black scabbardfish is unknown; however, the resource is being regarded as a nearly virgin stock (Machete et al., 2011). Based on the experience from other black scabbardfish fisheries, Machete et al. (2011) suggested that fishing mortality should be maintained at a low level, traditional fishing methods should be encouraged, and close monitoring of by-catch species should be implemented.

Economic and social performances

Annual landings and revenue of black scabbardfish fishery are extremely low (Figure 19). The average price per kilo of black scabbardfish has remained low at about 2.5€/kg, but has slightly increased to 4.1 €/kg since 2015. Official landings of black scabbardfish are reported mixed with silver scabbardfish (*Lepidopus caudatus*). The catch of silver scabbardfish is highly variable, and in recent years has been particularly high, explaining the higher landed values observed.

There is no information about the number of fishers involved in the drifting deep-water longline fishery. Morato (2012) estimated the number of direct jobs would be about 100 (4.5% of all fishers in the Azores) considering 10 crew members per vessel and 10 vessels operating in the Azores. This value has likely been lower in recent years.

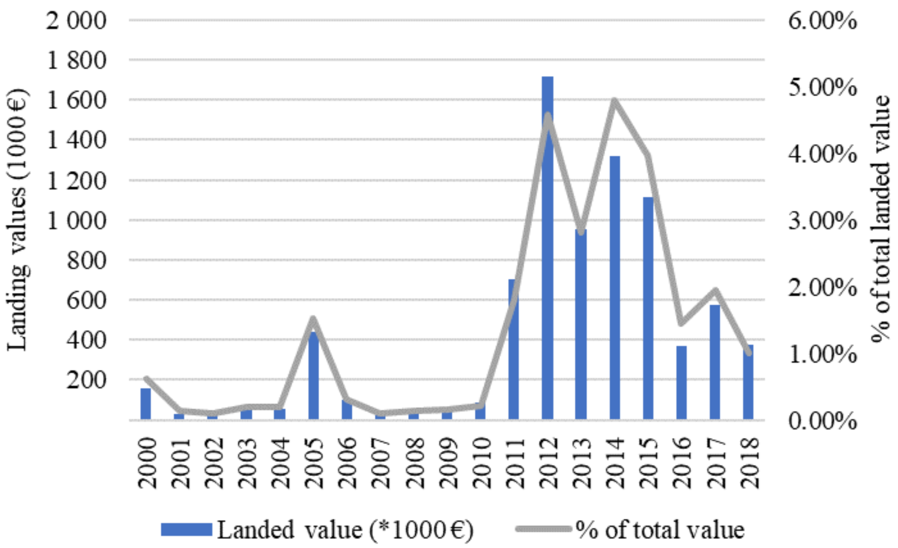


Figure 19. Landing values (in thousands of €) of scabbardfish (black scabbardfish and silver scabbardfish are reported mixed) declared in the Azores over the period 2000-2018, and percentage of the total value landed by all Azorean fisheries. Source: SREA, http://estatistica.azores.gov.pt, 2019.

Bycatch of sensitive species

Bycatch from the drifting longline fishery is of concern because they include many deep-water sharks listed in the IUCN red list of endangered species. In particular, the "endangered" leafscale gulper shark (*Centrophorus squamosus*) was estimated to account for 11.9% of the total catch of this fishery (Table 5), and was reported to occur in nearly 85% of fishing operations sampled by onboard observers (Fauconnet et al., 2019a; Machete et al., 2011). The "endangered" Portuguese dogfish (*Centroscymnus coelolepis*), and birdbeak dogfish (*Deania calcea*), the "least concern" Longnose velvet dogfish (*Centroscymnus crepidater*) and great lanternshark (*Etmopterus princeps*) are also common bycatch species of this fishery (Table 5). There is a growing concern with the bycatch of some of these species and, despite low catch records, it should be closely monitored (Machete et al., 2011). In 2018, a bycatch allowance of deep-water sharks of 10 t per year was granted to the drifting deep-water longliners targeting black scabbardfish, considering that this bycatch is difficult to avoid (Reg. EU 2018/2025). Despite this restrictive TAC for unavoidable bycatches being maintained, the Member States concerned were advised to develop regional management measures in this fishery with a view to reducing bycatches of deep-sea sharks. Specific data-collection measures for deep-sea sharks should also be established in order to ensure that those stocks are closely monitored (Reg. EU 2018/2025). There were no reports of cetacean or marine turtles capture, presence or interference in this fishery (Silva et al., 2011).

Table 5. Bycatch of deep-water shark species in the drifting deep-water longline fishery, with annual catch weights in tonnes per year (and 95% Confidence Intervals) by species, percentage of the species catch within the total catch of the fishery, and IUCN status based on the European Red List assessment performed in 2018. Source: Fauconnet et al., 2019a.

Scientific name	Annual catch (t)	CI Annual catch (t)	% of total catch	IUCN Status
Centrophorus squamosus	14.89	[14.89 - 14.9]	11.86	Endangered
Centroscymnus owstonii	1.12	[1.12 - 1.12]	0.89	Not Assessed
Centroscymnus crepidater	0.82	[0.82 - 0.83]	0.66	Least Concern
Etmopterus princeps	0.74	[0.73 - 0.74]	0.59	Least Concern
Centroscymnus coelolepis	0.65	[0.65 - 0.65]	0.52	Endangered
Etmopterus pusillus	0.36	[0.35 - 0.36]	0.28	Data Deficient
Deania calcea	0.35	[0.35 - 0.35]	0.28	Endangered
Deania profundorum	0.07	[0.07 - 0.07]	0.06	Data Deficient
Dalatias licha	0.04	[0.03 - 0.04]	0.03	Endangered
Centrophorus granulosus	0.02	[0.02 – 0.02]	0.02	Critically endangered
Zameus squamulosus	0.005	[0 - 0]	0.004	Data Deficient

Effects of fisheries on natural habitats

No major effects of drifting deep-water longline fisheries on natural habitats have been found in the literature. Since this gear has no contact with the sea bottom, it is not expected that drifting deep-water longline will have major effects on natural habitats (Morato, 2012).

2.2.2 Deep-sea mining

The recognition that the deep sea could provide a valuable source of scarce metals has become increasingly widespread in recent years (Petersen et al., 2016). Abundant sources of copper, zinc, silver and gold ores have been identified in Seafloor Massive Sulphide (SMS) deposits at deep-sea hydrothermal vents in many areas around the world (Hannington et al., 2011; Van Dover, 2011). In Areas Beyond National Jurisdiction (ABJN) along the Mid-Atlantic Ridge south of the Azores, significant SMS deposits have been identified (Cherkashov et al., 2010) and the ISA has approved two exploration contracts to Russia, France and Poland. North of the Azores, hydrothermal sulfide deposits are also known to occur on the Portuguese claimed extended continental shelf (e.g. in the Moytirra hydrothermal vent field) and on the ridge north of Iceland (Hannington et al., 2011; Wheeler et al., 2013).

To date, no commercial deep-sea mining has occurred in the Azores or anywhere in the world but the activity is likely to happen in the future and is anticipated to cause significant impacts on the marine environment and other human activities (Van Dover, 2011; Boschen et al., 2013; Wedding et al., 2015; Miller et al., 2018). The scale and nature of these impacts remain uncertain but will involve extensive physical destruction of the seabed, alteration in hydrothermal circulation at the active vent sites and production of considerable potentially toxic sediment plumes over both short and prolonged durations, depending on the size and duration of discharge, oceanographic conditions and dilution factors on different environments (Gwyther, 2008; Boschen et al., 2013). Predicted direct impacts on deep-sea ecosystems include the potential reduction in biodiversity, species abundance and ecosystem services, due either to loss of habitat or smothering of benthic communities by sediments in the close vicinity of the mining operations (Gwyther, 2008; Boschen et al., 2013; Van Dover et al., 2017). The organisms that are expected to be most affected by smothering are the benthic sessile fauna and the infauna, with reduced mobility that limits their escape capabilities. However, impacts of pelagic organisms are also expected, since 3-D oceanographic models predict a large horizontal and vertical mining plume dispersion (Morato et al., unpublished data), increasing turbidity and changing grain size and angularity (Lake & Hinch, 1999). Secondary effects include potential uptake of bioavailable trace metals released by sediment particles into tissues of marine organisms resulting in organisms' death and bio-accumulation of these metals through the food web (Brewer et al., 2007, 2012; Koski, 2012), and potential human health risks from fish and shellfish consumption (Reichelt-Brushett, 2012). Indeed, experimental studies conducted in the Azores in the framework of the EU MIDAS project (https://www.eu-midas.net/) suggest lethal and sub-lethal effects of mining sediment particles on octocorals and fish (Martins et al., 2018; unpublished data).

The seafloor around the Azores, including the extended continental shelf, may host mineable massive sulphide deposits (Kotlinski et al., 2015). The surrounding areas around Lucky Strike and Rainbow hydrothermal fields are examples of areas with interest for deep-sea seafloor massive sulphide exploration, but many other locations within the Azores EEZ and the extended claimed continental shelf might also be of interest (ISA, 2014; Beaulieu & Szafranski, 2019). The Azores EEZ may be the single EU Member States EEZ with sufficient mineral reserves offering promising possibilities for deep-sea mining in European waters (ECORYS, 2014). Nautilus Minerals Inc. has applied for exploration licenses for massive sulfide deposits, but the process is now on hold.

In 2006, international companies approached the Azores Government intending to explore minerals resources in the deep sea. In 2012, legislation for mineral exploration and exploitation in the Azores was created as well as legislation for granting access and equitable distribution of scientific results (following the Nagoya Protocol). A dispute with the Portuguese government that has ruled this legislation unconstitutional (ECORYS, 2014) has put things on hold. Nautilus Minerals Inc. submitted the first proposal for exploration rights in several areas, totalling 9272 km2, around the Azores (from North to South): Patorra (between Cavala and Ferradura seamounts), Moreto (south of the Menez Gwen hydrothermal vent field and close to Monte Alto and Voador seamounts), Arinto (south of Lucky Strike area, between Sarda and Farpas seamounts), Famous (in Famous hydrothermal vent field), Saldanha (in Saldanha hydrothermal vent), and Verdelho (around Rainbow hydrothermal vent fields) (Figure 20). Most of these areas were recently included in the Azores Marine Park (Section 2.3.2) as part of the PMA13 MPA, but lack effective protection measures (DLR n.º 13/2016/A). In fact, deep-sea mining exploration activities are not prohibited in PMA13, but they require special permits as it would be necessary for any other area.

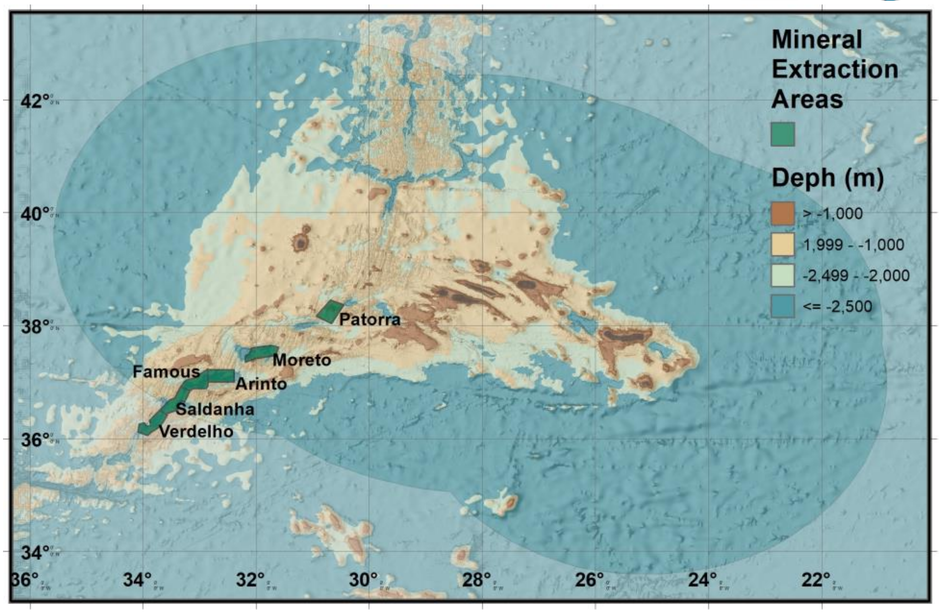


Figure 20. Location of the areas submitted by Nautilus Minerals Inc. for deep-sea SMS mining exploration in the Azores region.

2.2.3 Climate change

Climate change has been recognized as the greatest threat to marine ecosystems in the XXI century (IPCC 2019). Recent projections of deep-water mass properties suggested that portions of the seafloor in the North Atlantic will experience significant changes as a consequence of the uptake and storage of heat and anthropogenic carbon dioxide in the deep ocean (Gehlen et al., 2014; Sweetman et al., 2017; Perez et al., 2018). These forecasted changes may severely affect productivity, biodiversity, and distribution of deep-sea fauna, especially VME indicator species compromising key ecosystem services (Levin & Le Bris, 2015; Levin et al., 2019; Xavier et al., 2019; Morato et al., 2020; Puerta et al., 2020). In the North Atlantic, the bottom seawater properties were forecasted to change by 2100 with a decrease in seawater temperature in most of the area, a loss of dissolved oxygen up to 3.7%, a 40-55% decrease in the flux of particulate organic matter to the seafloor, a decrease in pH greater than 0.3 units in most area, and a decreases in the saturation horizon for calcite and aragonite (Figure 21).

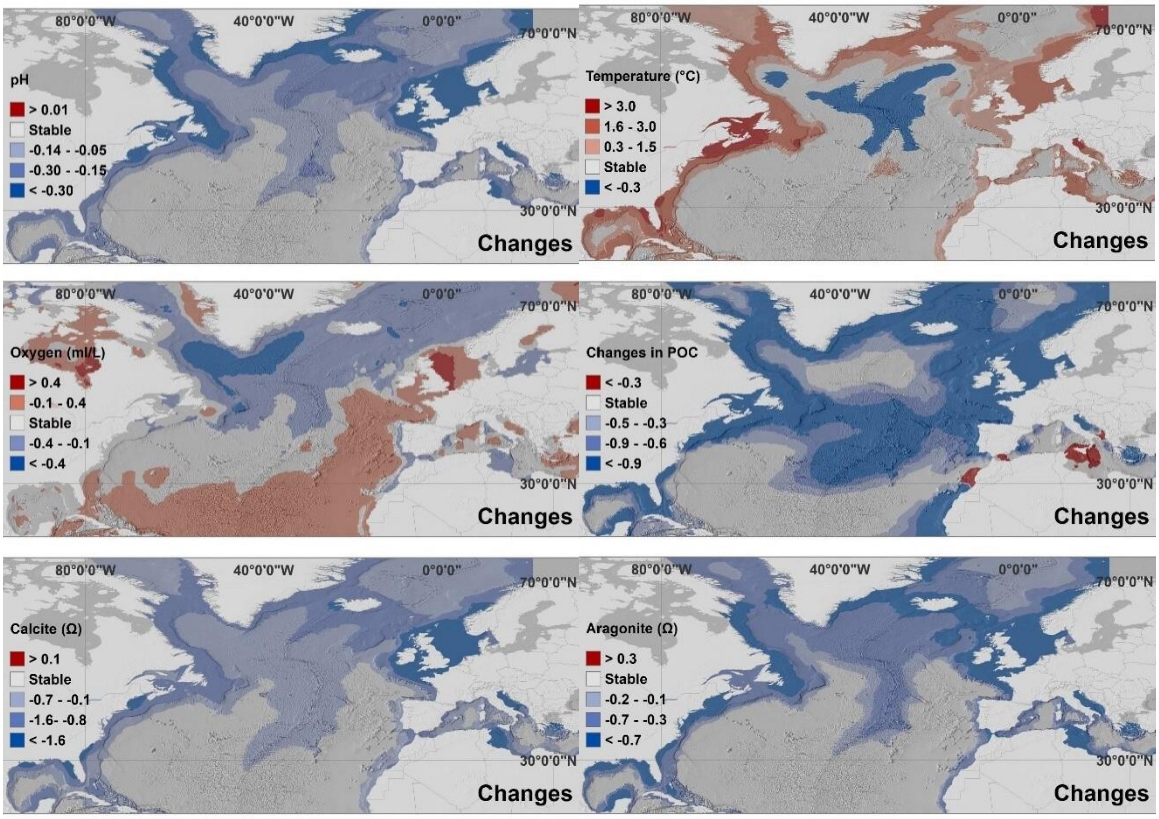


Figure 21. Changes in environmental predictors between present and future conditions in the North Atlantic Ocean.

These forecasted changes in the water mass properties of the deep North Atlantic were used to evaluate changes in the habitat suitability for key deep-sea species under future climate scenarios and at large spatial scales (Morato et al., 2020). Model predictions showed that CWCs and commercially important deep-sea fish species could be facing a reduction in their suitable habitat towards 2100 (Figure 22). Prediction showed a marked decrease of 30% to 100% in suitable habitat for cold-water corals and a marked shift in the suitable habitat of deep-sea fishes from 2.0° to 9.9° towards higher latitudes (Morato et al., 2020). The projections forecasted the largest reductions in suitable habitat for the scleractinian coral *Lophelia pertusa* and the octocoral *Paragorgia arborea*, with declines of at least 79% and 99%, respectively. ATLAS predicted an expansion of suitable habitat by 2100 for the fishes *Helicolenus dactylopterus* and *Sebastes mentella* by about 20 to 30%, mostly through northern latitudinal range expansion, corroborating the hypothesis of a poleward shift in response to climate change. In the Azores, a significant loss of suitable habitat was forecasted for most species. Experimental studies support these modelling predictions, showing that octocorals in the Azores are more vulnerable than scleractinian corals to predicted ocean acidification (Carreiro-Silva et al., 2014) highlighting the difficulties in making generalisations on the impact of climate change on deep-sea organisms (Xavier et al., 2019).

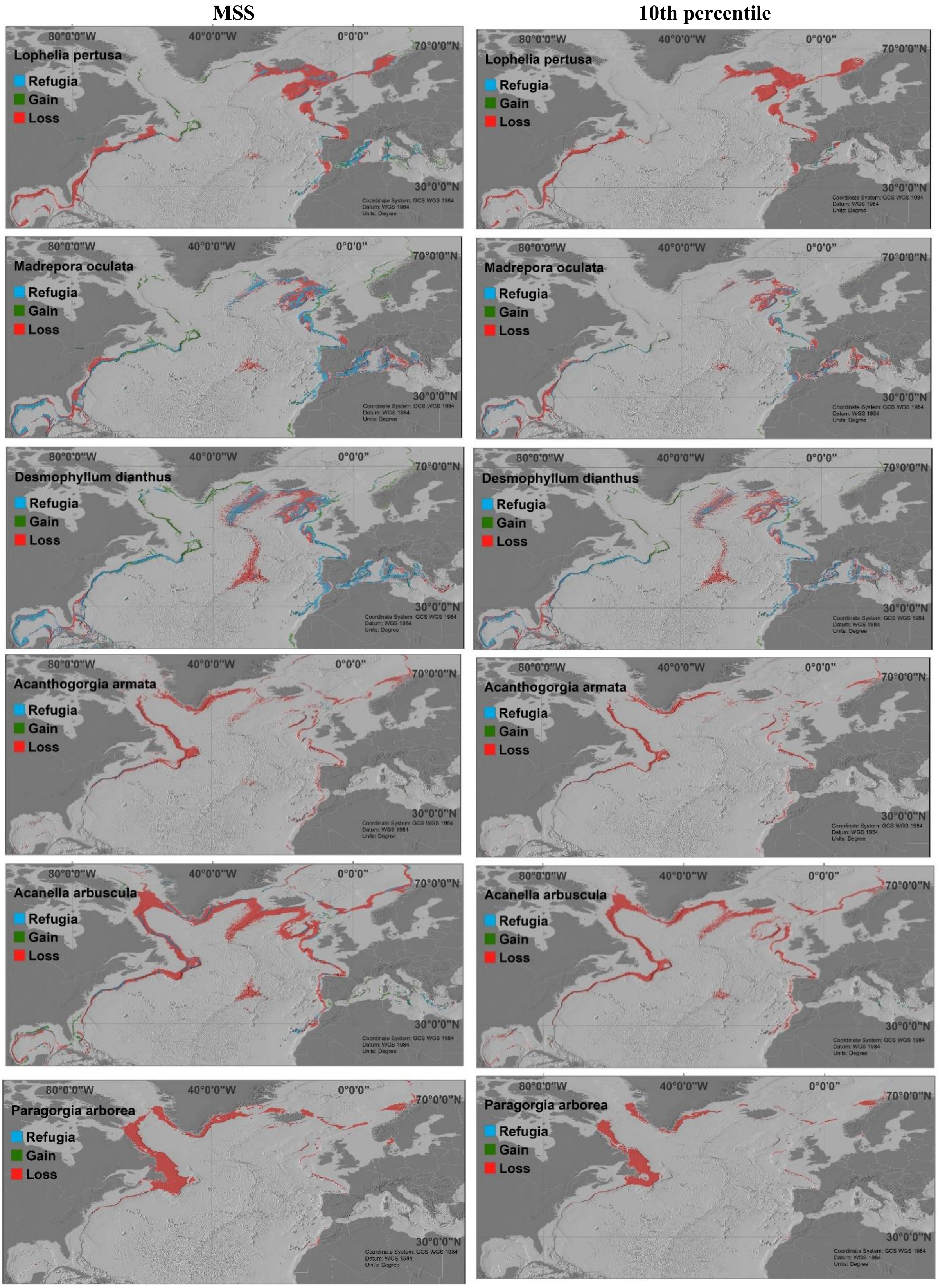


Figure 22. Forecasted present-day suitable habitat loss, gain, and acting as climate refugia areas (sensu Keppel & Wardell, 2012) under future (2081-2100; RCP8.5 scenario) environmental conditions for cold-water corals fish in the North Atlantic Ocean. Areas were identified from binary maps built with an ensemble modelling approach and two thresholds: 10-percentile training presence logistic threshold (10th) and maximum sensitivity and specificity (MSS).

2.3 Institutional landscape

2.3.1 Existing fisheries regulations

As with all EU Member States, the Azores Autonomous Region of Portugal is subject to a broad suite of international and national policies, laws and agreements controlling many sectors such as fisheries, energy and conservation. Consequently, there are many organizations and administrative bodies responsible for managing marine affairs. The current fishery resource management strategy of the Azores is based on the EU Common Fishery Policy, implemented primarily through TACs for various species including blackspot seabream, alfonsinos, and deep-water sharks (EC Reg. 2340/2002; EC Reg. 2270/2004). For deep-water sharks, a zero TAC has been implemented since 2010 for 13 taxa (EC Reg. 1359/2008), and since 2018 it was turned into a fishing prohibition (EC Reg 2018/2025). A zero TAC has also been implemented for orange roughy (*Hoplostethus atlanticus*), and since 2017 the species has also been declared "prohibited species". Fishing prohibition implies that under the European Landing Obligation (LO), all catch must be discarded (EC Reg 1380/2013). For the *Beryx* spp. quota, since *B. decadactylus* is less frequent and have higher commercial value than *B. splendens*, an "80% notice" has been implemented since 2013 to better manage the quota and limit the socio-economic impacts of quota closures. It means that whenever 80% of the mixed quota has been reached, the catch of *B. splendens* stops being allowed while up to 5% of *B. decadactylus* in the total catch can still be landed.

Apart from fish quotas, the regional government of the Azores has implemented technical measures over the years, such as minimum landing sizes or weights, minimum mesh sizes, limitation of licences for some specific gears (e.g. trammel nets), area temporal or permanent closures, and bans on the use of specific gear. The impact of fishing activities on benthic ecosystems has been a particular concern in the Azores, and bottom trawling and deep-sea netting are forbidden around the Azores since 2005 (European Council Regulation [EC] No. 1568/2005 of 20 September 2005; Santos et al., 2009b). Further protection of the deep sea throughout the Azores region was added in 2014 by the creation of an extensive fishery management area that encompasses most of the Portuguese extended continental shelf where bottom-trawling is banned, and by setting move-on rules for the incidental capture (bycatch) of corals and sponges (Portaria 114/2014). Also, a 100 miles' polygon around the islands limiting the fishing to vessels registered in the Azores was created in 2003 (EC Reg. 1954/2003), and revised in 2013 (EC 1380/2013) and in place until December 2022.

Other spatio-temporal limitations applying to the bottom longline and handline fishery include a seasonal fishing closure for blackspot seabream. This closure has been implemented in one to two winter months in January and/or February from 2015 to 2017 (Portaria 74/2015, Portaria 88/2016, Portaria 13/2017) and was amended in 2017. Spatial fishing restrictions relative to gear type have also been implemented for bottom longliners and handliners: i) longliners are not allowed to fish within 3 nm from shore, ii) longliners may only fish from 3 to 6 nm from shore in São Miguel and Terceira but only for the vessels registered in those islands or having them as home ports, while in the other islands such allowance was only given in some period; iii) for handliners, vessels ≤14m are not allowed within 1 nm from the coast, this limit is set to 3 nm for the vessels >14m, and 30 nm for vessels >24m (Reg Portaria 50/2012).

2.3.2 Existing conservation regulations

There has been a long history of marine conservation in the Azores (see Abecassis et al., 2015) that started back in the 1980s with the establishment of six coastal MPAs and one offshore marine reserve encompassing the Formigas islets and Dollabarat reef, that imposed fishing limitations to promote the sustainable use of marine resources (Martins & Santos 1988; Santos et al., 1995). In the 1990s, the Azores was highly involved in the implementation of many EU-driven initiatives, namely the EU Habitats and Birds Directives that supported the creation of the Natura 2000 network of MPAs. During this period several research projects, led by the University of the Azores and in close collaboration with the Regional Government, helped to gather baseline information for the establishment MPA in the Azores (Abecassis et al., 2015) and the identification of many sites of community importance (SCIs), and special areas of conservations (SACs). During the 2000's a joint effort between the Regional Government of the Azores and the University of the Azores resulted in eleven applications of sites to be included in the OSPAR network of MPAs: seven within national waters and four outside national jurisdiction but within the limits of the areas proposed for legal continental shelf extension that Portugal submitted to the United Nations Commission on the Limits of the Continental Shelf. This made Portugal, and particularly the Azores, a pioneer in the protection of marine biodiversity at an international level (Ribeiro, 2010) and a progressive player that helped to progress the ground-breaking OSPAR high seas MPAs process (Abecassis et al., 2015). Many of these MPAs applications were supported by the presence of priority habitats (cold-water gardens and reefs, sponge aggregations, hydrothermal vent fields), and species (orange roughy). In the late 2000s, the UNESCO approved the applications submitted to the Man and Biosphere Program, recognizing the islands of Corvo, Flores and Graciosa and their surrounding marine environment as Biosphere Reserves.

More recently, the Azores Network of Marine Protected Areas was set up by the regulation "Decreto Legislativo Regional nº 15/2007/A" with the overall objective to protect and restore biodiversity and habitats, particularly in the deep sea, that have been negatively affected by human activities, or might be negatively affected in the future. The Azores Network of Marine Protected Areas includes the Island Natural Park within the territorial waters (12nm) and the Azores Marine Park beyond territorial waters. The network of protected areas declared in the Azores Marine Park is the main instrument for marine biodiversity conservation in the deep-sea beyond territorial waters (12nm). It is coordinated by the Regional Directorate for Maritime Affairs (DRAM) together with an advisory council. Eleven MPAs were included in the Azores Marine Park in 2011 (DLR n.º 28/2011/A), while the MPA of the Meteor Submarine Archipelago (PM12), seamounts Condor and Princesa Alice (PM14 and PM15, respectively) and a large area in the Mid Atlantic Ridge southwest of Flores were included in 2016 (DLR n.º 13/2016/A). With the 2016 update defined in the regulatory decree-law nº 13/2016/A and 2019 addition of the Luso hydrothermal vent field defined in the Portaria nº 68/2019, the Azores Marine Park is now composed of 16 Marine Protected Areas, covering an area of 135,507 km both within and partially beyond the Portuguese EEZ (Figure 23):

- Five hydrothermal vent sites: Banco Dom João de Castro, Menez Gwen Hydrothermal Field, Lucky Strike Hydrothermal Field, Rainbow Hydrothermal Field, and Luso hydrothermal vent field
- Six seamounts; Sedlo, Altair, Antialtair, Banco Dom João de Castro, Condor and Princesa Alice
- Two offshore areas of importance for seabirds; the Corvo Oceanic MPA and the Faial Oceanic MPA
- Three extensive areas in the Mid-Atlantic Ridge South and the Mid-Atlantic Ridge north of the Azores (MARNA), and the Meteor Submarine Archipelago, South of the Azores.

In addition to these areas, the Marine Reserve of the Formigas islets regulated under the Santa Maria Island Natural Park (Decreto Legislativo Regional n.º 39/2012/A), is also a relevant MPA for marine biodiversity conservation in the deep-sea. All the areas regulated under this network fall within several IUCN categories (IUCN, 2008; Calado et al., 2011): nature reserves (IUCN I); protected areas for management of particular habitats or species (IUCN IV); and marine protected areas for resource management (IUCN VI). Broadly speaking, those MPAs can be separated between two categories: the Marine Natural Reserves (IUCN I) that constitute permanent bottom-fishing closures and thus ensure the full protection of the seabed and the demersal species, and the other MPAs where fishing activities are regulated but not prohibited (Figure 23).

The Marine Protected Area of seamount Don João de Castro (PMA1) includes a small Marine Natural Reserve that encompasses shallow (20 m) hydrothermal vents (IUCN category I), which in turn are encompassed by a larger Marine Protected Area for resource management (PM11, IUCN Category VI). This seamount is also classified as an EU Natura 2000 site. The hydrothermal vents Menez Gwen (PMA 2) and Lucky Strike (PMA3) are also Nature Reserves and are protected against bottom contact fishing, deep-sea mining, dumping and other activities that may cause harm to the marine environment (IUCN category I; DLR 28/2011/A). The Rainbow (PM4) vent field is a Nature Reserves located in the continental shelf behind 200nm claimed by Portugal, but it lacks effective protection measures (DLR 28/2011/A). The Menez Hom, Famous, Saldanha, and Amar vent fields (PMA13), also lack effective protection measures (DLR 13/2016/A). In fact, deep-sea mining exploration activities are not prohibited in PMA13, but they require special permits as it would be necessary for any other area. The Luso hydrothermal vent field is fully protected from fisheries since September 2019 (Portaria 68/2019). However, the regulation does not mention other activities rather than fisheries, and therefore deep-sea mining exploration and scientific research were not subject to specific rules or prohibitions.

As for the seamounts within the network, the Sedlo and the Formigas seamounts are Natural Reserves with fisheries restrictions to all types of gears except epipelagic fishing, deep-sea mining, dumping and other activities that may cause harm to the marine environment (IUCN, Category I), while the Condor and Princesa Alice seamounts are marine protected areas for resource management (IUCN VI). The Condor seamount also benefits from strong protection, as it was closed in 2010 to bottom fishing for research purposes (Portaria 48/2010) and until 2020 (Portaria 94/2017). The MPA of Princesa Alice seamount protects only the summit of this feature. Offshore seamounts beyond the Azorean EEZ (Altair, Antialtair), MARNA and the Meteor seamount complex are protected for resource management under IUCN category VI, but in practice, they lack effective protective measures.

Very few MPAs have been declared to achieve conservation goals related to large megafauna, including seabirds. The exception are the Offshore MPAs North of Corvo and North of Faial which were designated as Marine Important Bird Areas (MIBAs) for the protection of the Cory's Shearwater (*Calonectris diomedea*). Afonso et al. (2020) proposed an action plan for marine megafauna research and conservation centred in the Azores that could include an expansion of the Azores Marine Park to encompass Essential Marina Habitats for multiple megafauna species.

The seamounts and hydrothermal vents mentioned above are also listed under the OSPAR network of MPAs (OSPAR, 2017), aiming at protecting the biodiversity of the waters superjacent to the seabed. The Meteor submarine Archipelago has also been proposed an Ecological or Biologically Significant Area (EBSA) to the secretariat of the Convention on Biological Diversity (CBD) by Portugal in 2019. Menez Gwen and Lucky Strike hydrothermal vent fields are also classified as Sites of Community Interest (SCI) under the EU Habitats Directive and included in the Natura 2000 EU-wide network of protected areas (Natura, 2007).

However, most Azorean MPAs have had little results in attaining conservation or restoration objectives (Schmiing et al., 2014; Afonso et al., 2018). Abecassis et al. (2015) have thoroughly discussed this topic and provided a reflection on possible ways forward to increase the success of such area-based management tools.

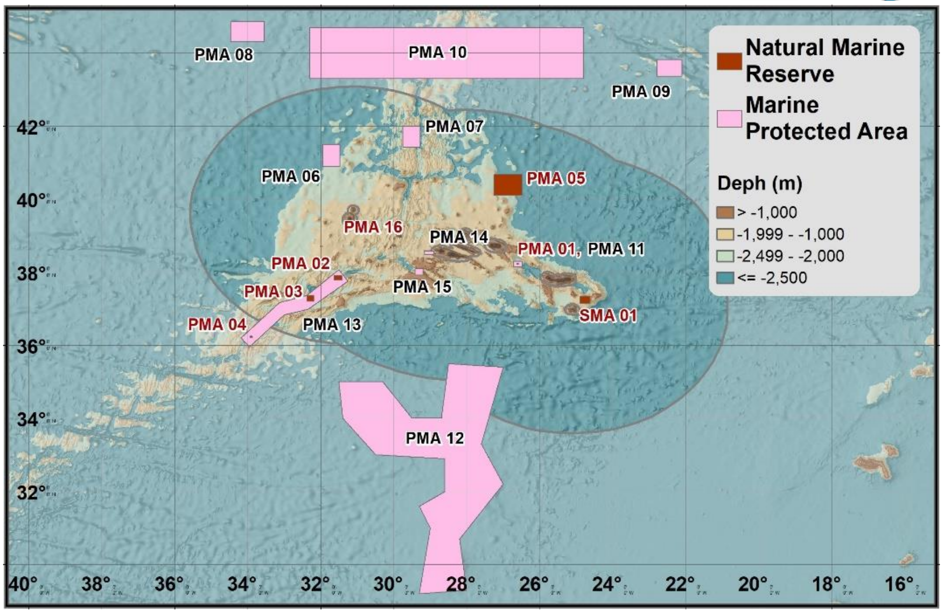


Figure 23. The existing network of the marine protected areas relevant for biodiversity management and conservation in the deep-sea of the Azores. Five hydrothermal vent sites, Banco Dom João de Castro (PMA01), Menez Gwen (PMA02), Lucky Strike (PMA03), Rainbow (PMA04), and Luso hydrothermal (PMA16); six seamounts, Sedlo (PMA05), Altair (PMA08), Antialtair (PMA09), Banco Dom João de Castro (PMA11), Condor (PMA14) and Princesa Alice (PMA15); two offshore areas, the Corvo Oceanic MPA (PMA06) and the Faial Oceanic MPA (PMA07); three extensive areas in the Mid-Atlantic Ridge South (PMA13) and north (PMA10) of the Azores (MARNA), and the Meteor Submarine Archipelago (PMA12); and the Formigas islet (SMA01).

3. Principles, goals and objectives

3.1 Guiding principles

The systematic conservation planning (SCP) for the deep-waters of the Azores EEZ was guided by a set of general principles that determined the nature and characteristics of the scenarios developed here, and the criteria, decisions and choices adopted. These general principles were adapted from Ehler & Douvere (2009) and Dunn et al. (2018).

- ***Science-based principle***: The SCP was based on the best available information gathered from all available sources and supported by the best available science-based evidence.
- ***Precautionary Principle***: When information was considered to be inadequate or insufficient to justify a decision, then the safest possible choice must be made.
- ***Adaptive approach principle***: The SCP was designed to be improved or redeveloped whenever new information is available. SCP should be a continuing, iterative process that improves and adapts over time.
- ***Ecosystem integrity principle***: The SCP for the deep-waters of the Azores EEZ had a primary focus on maintaining ecosystem structure and functioning within the spatial planning area.
- ***Ecosystem-based approach principle***: The SCP was based on an ecosystem approach to ensure sustainable use of marine resources while protecting and preserving the marine environment, safeguarding the variety of marine landscapes, habitats and interactions within an ecosystem, including human activities.
- ***Transparency principle***: The process used to develop SCP scenarios aimed to be transparent, objective, and easily understood.
- ***Maintain native species diversity principle***: SCP was designed to maintain or restore species diversity, composition, and functional redundancy

3.2 Management and Conservation Goals

Defining management and conservation goals and objectives is an essential step toward the implementation of area-based management tools and be derived from specific problems or conflicts previously identified (Ehler & Douvere, 2009). Having these goals and objectives clearly defined, helps to focus and tailor systematic conservation planning scenarios toward achieving such results. For transparency reasons, here, we followed the Ehler & Douvere (2009) and Ehler (2014) definitions:

- **Goal**: a statement of general direction or intent. Goals are high-level statements of the desired outcomes to be achieved;
- **Objective**: a specific statement of desired outcomes that represent the achievement of a goal. Objectives should be SMART (Specific, Measurable, Achievable, Relevant or Realistic, and Time-bound).

Such goals and objectives need to be discussed among all stakeholders, so the purposes for implementing area-based management tools are clear, understood, and agreed. These goals and objectives can have multiple dimensions usually grouped into ecological, economy, social or governance goals (Ehler & Douvere, 2009). Here we focused on environmental and simplified economic goals and objectives only, since the government goals should be translated from other overarching strategies. Following the existing regional, national and international regulations and guidelines we based this study in the broad ***overarching mission statement*** of:

protecting ***ecosystem structure***, ***function***, ***natural diversity***, ***connectivity,*** and ***resilience*** of deep-sea communities in the Azores EEZ in a ***changing planet***, while allowing a socially equitable and environmentally ***sustainable use*** of natural resources for current and future generations. Based on this overarching statement, several systematic conservation planning goals were put forward (Table 6).

Table 6. Management goals adopted for the development of the systematic conservation planning scenarios for the deep-waters of the Azores EEZ, based on the broad overarching mission statement of protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores EEZ in a changing planet, while allowing the environmentally sustainable use of natural resources for current and future generations.

Overarching mission	Ecological Goals
Ecosystem structure	• Ensure protection of intact and restoration of degraded Vulnerable Marine Ecosystems; • Maintain food-web structure and networks of trophic relationships in ecosystems;
Ecosystem function	• Ensure protection of intact and restoration of degraded of essential deep-sea habitats; • Ensure protection of intact and restoration of keystone and foundation species; • Ensure the long-term maintenance of biologically mediated processes; • Maintain functional diversity of deep-sea ecosystems;
Protect natural diversity	• Maintain or restore biological diversity of deep-sea ecosystems at all its levels; • Ensure protection of vulnerable, endangered, or critically endangered species or habitats; • Ensure protection of hotspots of biodiversity of deep-sea ecosystems; • Ensure protection of potential near natural areas; • Ensure the protection of representative benthic habitats and associated ecosystems;
Connectivity	• Ensure protection of a network of connected areas that benefit from larval and/or species exchanges and other functional linkages;
Resilience	• Maintain long-term ecosystem resilience to natural and anthropogenic disturbances and stressors;
Changing planet	• Maintain long-term biological diversity, ecosystem structure and function of the deep-sea ecosystems under future climate conditions;
Sustainable use of natural resources	• Maintain healthy fish stocks in the long term; • Rebuild and restore fish stocks of commercially important deep-sea benthic species; • Ensure protection of essential fish habitats of commercially important deep-sea benthic species.

3.3 Management and conservation Objectives

Monitoring and evaluating progress toward the achievement of desired outcomes can only be measured when objectives are specific, measurable, achievable, relevant, and time-bound (i.e., SMART) (Ehler & Douvere, 2009). Preliminary objectives are very often used as indicative of the expected outcome to be achieved in a specific time-frame and should always be re-examined later in the process. Based on the planning goals described above, we put forward some preliminary SMART objectives to guide the planning scenarios for the deep-waters of the Azores EEZ (Table 7). It should be highlighted that the measurable and time-bounded components of these objectives are merely indicative and should be revised and agreed with all stakeholders.

Table 7. Preliminary objectives adopted for the development of the systematic conservation planning scenarios for the deep-waters of the Azores EEZ, based on the management goals defined in Table 6.

Overarch. Goal	Ecological Goals	Objectives
Ecosystem structure	Ensure protection of intact and restoration of degraded Vulnerable Marine Ecosystems	• Ensure full protection (100%) of bona fide Vulnerable Marine Ecosystems by 2023 • Protect at least 30% of known records of endemic, extremely long-lived, and reef engineers Vulnerable Marine Ecosystems indicators by 2023 • Protect at least 15% of inferred Vulnerable Marine Ecosystems by 2023
	Maintain food-web structure and networks of trophic relationships	•
Ecosystem function	Ensure protection of intact and restoration of essential deep habitats	• Protect a minimum of 75% of the known essential deep-sea habitats by 2023
	Ensure protection of intact and restoration of keystone and foundation species	• Ensure the identification of keystone and foundation species by 2025 • Protect a minimum of 30% of the known keystone and foundation species distribution by 2028
	Ensure the long-term maintenance of biologically mediated processes	•
	Maintain functional diversity of deep-sea ecosystems	•
Protect natural diversity	Maintain or restore biological diversity of deep-sea ecosystems at all its levels	• Ensure no further loss of deep-sea biodiversity at ecologically relevant scales by 2030
	Ensure protection of vulnerable, endangered, or critically endangered species or habitats	• Halt significant adverse impacts on vulnerable, endangered, or critically endangered species or habitats by 2030
	Ensure protection of hotspots of biodiversity of deep-sea ecosystems	• Protect a minimum of 75% of the known hotspots of biodiversity of deep-sea ecosystems by 2023
	Ensure protection of potential near natural areas	• Protect at 100% of the near-natural habitat within current fishing depths by 2023
	Ensure the protection of representative deep-sea benthic habitats and associated ecosystems	• Ensure that at least 15% of all deep-sea benthic habitats and associated ecosystems are protected by 2023
Connectivity	Ensure protection of a network of connected areas that benefit from larval and/or species exchanges and other functional linkages	• Ensure the connectivity patterns, larval dispersal distances and average annual mobile animals movements of deep-sea foundation, keystone, vulnerable, and economically important deep-sea species are revealed by 2030 • Ensure the maximum distance between the units of the network are not greater than the 75th percentile of median larval dispersal distances and average annual mobile animals movements by 2033
Resilience	Maintain long-term ecosystem resilience to natural and anthropogenic disturbances and stressors	•
	Maintain long-term biological diversity, ecosystem structure and function of the deep-sea ecosystems under future climate conditions	• Ensure the identification of areas with least climate hazards and climate refugia areas for deep-sea biodiversity and commercially important deep-sea benthic fish by 2025 • Protect a minimum of 75% of the climate-resilient and climate refugia areas by 2028
Sustainable use of natural resources	Maintain healthy fish stocks	•
	Rebuild and restore fish stocks of commercially important deep-sea benthic species	• Rebuild fish stocks of commercially important deep-sea benthic species to those levels prior to the 1990's by 2040; • Protect at least 15% of suitable habitat of commercially important deep-sea benthic fish species by 2023
	Ensure protection of essential fish habitats of commercially important deep-sea benthic species	• Ensure the identification of essential fish habitats of commercially important deep-sea benthic species by 2025 • Protect a minimum of 50% of essential fish habitats of commercially important deep-sea benthic species by 2028

3.4 Design criteria

The development of the systematic conservation planning scenarios for the deep-waters of the Azores followed six design criteria adapted from CBD (2008), Dunn et al., (2018) and informed by several reviews on guiding ecological principles for marine spatial planning (Foley et al., 2010; Katsanevakis et al., 2011; Wedding et al., 2013; Long et al., 2015) were adopted and then used to assess the performance of the different scenarios. The six design criteria were:

- ***Important Areas***: Based on the science-based principle these areas as defined as those features that based on the current best available knowledge are considered of ecologically or biologically importance. Placement of closures should fully capture the Important Areas most suitable to achieve the planning goals;
- ***Important resources***: Defined as those species, habitats or functions considered most suitable to achieve the management and conservation goals. A prioritization approach is used to complement the Important Areas with areas that based on current best available knowledge contain important resources and are considered the most suitable to achieve the planning goals. Placement of closures should partially capture areas with important resources necessary to achieve the representation targets;
- ***Representativity***: Placement of closures should conserve similar proportions of all seabed habitats and important resources within the spatial planning area. When the science-based principle can't be applied, a Representativity approach should be applied;
- ***Connectivity***: Spacing of closures should ensure dispersal and connectivity across the entire spatial planning area, minimizing the average and maximum spacing between areas;
- ***Replication***: Closures should be replicated within spatial planning area to capture local variations and protect against failures;
- ***Viability and Adequacy***: The number, size and location of closures in the network should be suitable to achieve the planning goals, warrant compliance and efficient enforcement, consider existing area-based management tools, and capture at least 15% of the spatial planning extent;
- ***Resilience to climate change and other stressors***: Placement of closures should account for climate change hazards, climate velocities, climate representative areas, and expected climate change impacts.

4. Systematic conservation planning approach

Systematic conservation planning is an explicit, objective-based and quantitative approach to inform the selection of priority areas for conservation to achieve specific management goals and objectives (Margules & Pressey, 2000). The systematic conservation planning approach used here, is based on a multiple step framework (Figure 24) aiming to develop multiple fisheries closures scenarios to inform the selection of "no-take areas" for achieving certain conservation and management goals in the deep-sea of the Azores Exclusive Economic Zone (EEZ). This approach could be seen as a decision tree that should be revised whenever necessary (Figure 24).

1- Identify a set of ***management and conservation goals and objectives*** along with guiding principles and design criteria that determined the nature and characteristics of the scenarios developed (Section 3). These goals and objectives should be agreed with stakeholders;

2- Define the ***spatial planning area*** to be considered in the systematic conservation planning (Section 4.2). Based on the "science-based" principle, the spatial planning area was divided into "data-rich" and "data-poor abyssal" spatial planning areas;

3- Identify the ***Important Areas*** that based on current best available knowledge (data-driven approach) are features of particular ecologically or biologically importance and the most suitable to achieve the planning goals (Section 5.1). These areas should always be included in the scenarios' solutions (a.k.a. locked-in areas);

4- Identify the ***Important Resources*** that are defined as those species, habitats or functions considered most suitable to achieve the management and conservation goals (Section 5.1). A prioritization approach is used to complement the Important Areas with areas that based on current best available knowledge (data-driven approach) contain important resources. Placement of closures should partially capture areas with important resources necessary to achieve the representation targets (a.k.a. conservation features);

5- ***Compile the best available data*** on biological and environmental conditions, as well as human uses, in the planning area (Appendix 1). A particular focus should be given to collect information that would specifically address the agreed management goals and objectives. Also extremely important, is to ***identify the main knowledge gaps*** and to develop active efforts to fill those gaps;

6- Identify the ***cost model(s)*** to be used in the prioritization approach (Section 5.3) and that could target areas with high conservation potential regardless of the existing human uses or target areas with high conservation potential while minimizing impacts on existing activities;

7- Define the ***configuration of the network*** of closed areas (i.e. number and size of individual clusters), implemented in the prioritization approach by setting different values for the boundary penalty that penalises fragmented solutions using a matrix of shared boundary length between different PUs;

8- Define the ***Prioritization targets*** which should include both the Spatial planning closure targets (i.e. the proportion of the spatial planning area to be included in the prioritization solutions) and the conservation features' representation targets;

9- Implement a ***spatial prioritisation tool*** to complement the Important Areas with areas with Important Resources necessary to achieve the prioritization targets. Among many prioritisation tools, the "minimum set" approach, used by the Marxan software, is the most widely used framework in the world for informing marine and terrestrial protected area systems;

10- Preform a ***performance assessment*** of the planning scenarios solutions against the design criteria;

11- Forecast the ***ecosystem level outcomes***, including the human activities, of the implementation of scenarios;

12- ***Repeat the process*** until multiple options are evaluated and agreed or whenever new information is made available (i.e. Adaptive approach principle).

13- Complement the data-driven prioritization approach with a ***representativity and connectivity approach*** design to identify representative areas of all seabed habitats and to achieve the prioritization targets when information was considered to be inadequate or insufficient to justify a data-driven approach and to increase the connectivity of the whole network.

It should be stressed up front that the objective of this study is not to indicate the preferred design and placement of fisheries closures in the Azores, but rather to develop systematic conservation planning scenarios that can inform the discussions around this topic.

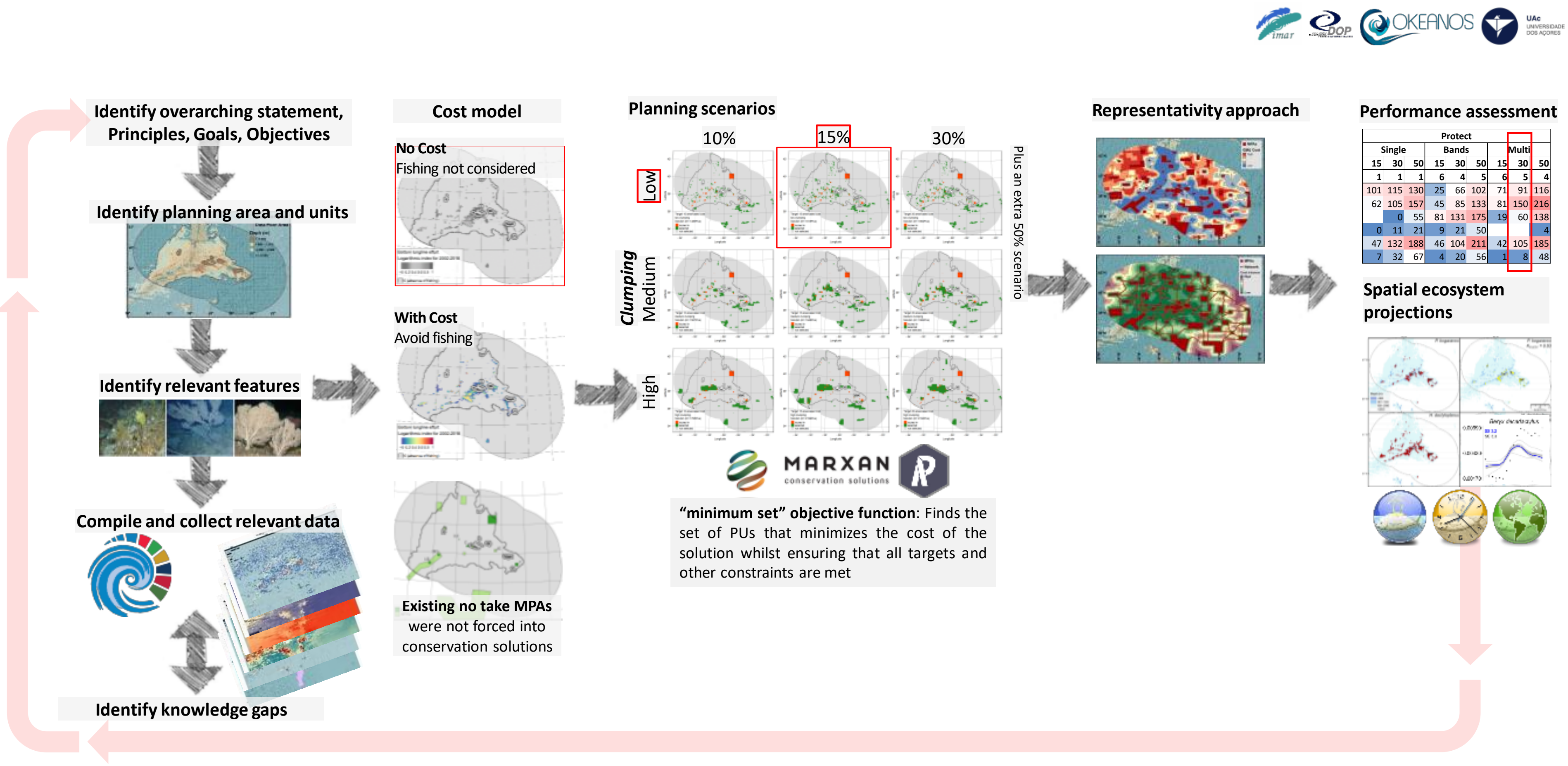


Figure 24. The systematic conservation planning approach used to develop multiple fisheries closures scenarios to inform the selection of "no-take areas" for achieving certain conservation and management goals in the deep-sea of the Azores Exclusive Economic Zone (EEZ).

4.1 Conservation prioritization methodology (PrioritizR)

Systematic conservation planning can be implemented through the use of prioritization algorithms coupled with spatially explicit data to optimize the outcomes and reduce potential conflicts transparently and objectively. Among many conservation planning tools, the "minimum set" approach, used by the Marxan software, is the most widely used framework in the world for informing marine and terrestrial protected area systems (Watts et al., 2017). Key-terms used in such spatial conservation planning approaches are summarized in Box 1.

The "minimum set" approach is largely grounded to find the set of planning units that minimizes the cost of the solution while ensuring that all feature representation targets and other constraints are met (Ball et al., 2009). The spatial prioritization is implemented on a gridded planning area where each grid square represents a planning unit (PU) that can be either selected or excluded from the conservation solution, i.e. the set of planning units better suited to achieve the management objectives. The conservation solutions resulting from the prioritization are highly sensitive to the goals and objectives defined and, most importantly, are highly sensitive to conservation features used in the approach. Therefore, the conservation features should be carefully selected to address specific conservation objectives, following the guiding principles and considering the design criteria. Typically, quantitative representation targets are set for each of those features, and the algorithm optimizes the selection of PU in order to minimize either the total area to conserve or the socioeconomic cost of the conservation solution. Further spatial constraints or penalties can be added to address network properties goals, by adjusting the location, size and spacing of selected areas.

Box 1. Key-terms frequently used in spatial conservation planning frameworks such as the "minimum set" approach (adapted from Ardron et al., 2010; Daigle et al., 2018; Hanson et al., 2019)

- ***Planning region***: the study area over which the spatial planning exercise is taking place.
- ***Planning unit*** (PU): a spatial unit resulting from the subdivision of the planning region.
- ***Conservation feature***: the conservation features of interest for achieving certain conservation goals and objectives. These features are usually aligned with the guiding principles and design criteria and should be science-based, and capture important resources, important areas, representativeness, and connectivity. In the simulations, a feature's distribution can be split into several pseudo-features according to a criterion (e.g. temporal, spatial, categorisation of an index). This allows for assigning different representation targets to the pseudo-features considering the criteria. Pseudo-features were applied to the seabed units for which representativity targets varied according to the "data-rich" and "data-poor abyssal" planning areas.
- ***Conservation target***: the minimum amount or proportion of a feature's distribution in the study area that has to be included in solutions.
- ***Cost***: a relative measure of the cost of protecting a planning unit. An area-based cost, which is identical for all the planning units, will lead to minimizing the area of the network only. A more complex cost, based on socio-economic activities, allows for varying the individual value of PUs according to a metric. Such socio-economic cost can represent an acquisition cost (likely used in land-based SCP), the foregone value of economic activity (namely an opportunity cost), or the easiness-to-implement management (Ban & Klein, 2009).
- ***Penalties***: a penalty associated with a specific metric which will act as a trade-off on the cost of planning units. The "boundary penalty" increases the cost of setting more spatially fragmented solutions, and thus favours larger but less numerous areas as the penalty is increased. We used the term **clumping** to represent different levels of boundary penalties.
- ***Constraints***: spatial requirements applied on the conservation solution, e.g. exclude or include certain planning units. More commonly, the protected areas already in place are locked in solutions so the algorithm complements the existing protection network.
- ***Solution***: a binary output resulting from problem-solving and displaying the selected (1) and not selected (0) planning units for the conservation plan.

In this study, a spatial prioritisation approach was implemented with the PrioritizR package (Hanson et al., 2019) on R environment (R Core Team, 2018), interacting with the Gurobi optimisation software (Gurobi Optimization LLC, 2018). PrioritizR is a recent R package that uses integer linear programming instead of conventionally heuristics or simulated annealing algorithms (e.g. in Marxan, Ball et al., 2009). Integer linear programming has been shown to present several advantages compared to other methods, such as the measure of solutions optimality (Beyer et al., 2016; Rodrigues & Gaston, 2002) and provided results to inform practical conservation planning (Schuster et al., 2019; Tack et al., 2019).

We used a "minimum set" function consisting of an integer linear programming problem that can be expressed in matrix notation (Hanson et al., 2019) as: minimize cx subject to $Ax \geq b$. Here x is a vector of decision variables (whether to select or not a planning unit), c and b are vectors of known coefficients, and A is the constraint matrix. In the "minimum set" function, c represents a vector of costs for each planning unit, A stores the amount of each feature in each planning unit, b is a vector of representation targets for each conservation feature, and the total amount of each feature in the solution must exceed the quantities in b. This means that the most basic conservation problem will consider the distribution of conservation features, their respective conservation target, and the cost associated to planning units. A conservation problem can be further detailed by adding penalties acting on c, or constraints acting on A.

The "minimum set" objective function when translated into an integer linear programming problem can be expressed in matrix notation (Hanson et al., 2019) as: minimize cx subject to $Ax \geq b$. Here x is a vector of decision variables (whether to select or not a planning unit), c represents a vector of costs for each planning unit, b is a vector of representation targets for each conservation feature, and A is the constraint matrix storing the amount of each feature in each planning unit. The sign $\geq$ means that the total amount of each feature in the solution must exceed the quantities in b. This means that the most basic conservation problem will consider the distribution of conservation features, their respective conservation target, and the cost associated with planning units. A conservation problem can be further detailed by adding penalties acting on c (e.g. increase the cost of PUs if they are too fragmented in the solution), or constraints acting on A (e.g. certain PUs must always be included in the solution).

4.2 Spatial planning boundaries

The spatial planning area considered in this systematic conservation planning (SCP) approach was the deep sea of the Portuguese EEZ around the Azores archipelago; sometimes also referred to as the Azores EEZ. The deep sea is a diffuse concept traditionally used to name areas of the ocean that are deeper than 200m depth, where the sunlight starts to fade. This definition applies well to continental shelf areas where shelf-breaks usually start at around those depths. However, in offshore volcanic islands and archipelagos, such as the Azores, the deep sea starts close to the island shores (Figure 25) where many typical coastal activities and users overlap. The coastal areas concentrate most of the shallow-water ecosystems and harbour complexity and multiplicity of uses and stakeholders that are not directly linked with the deep sea context. Moreover, there are specific spatial fisheries regulations set to manage coastal areas up to 1, 3 and 6 nm from the coastline. An example is the prohibition of bottom longline fishing within 3 nm of all islands and within 6nm from the shores of most islands. Therefore, for this SCP approach, which excludes the coastal area, the spatial planning area boundary was defined by existing fisheries regulation and excluded areas within 6 nm from the island's shores. This boundary was regarded as the most adequate separation between coastal and deep-sea environments. The SCP for coastal areas within the 6nm boundary would require to be addressed at a local scale (island by island) and with a higher spatial resolution that are incompatible with the large spatial scale of the deep-sea area considered here.

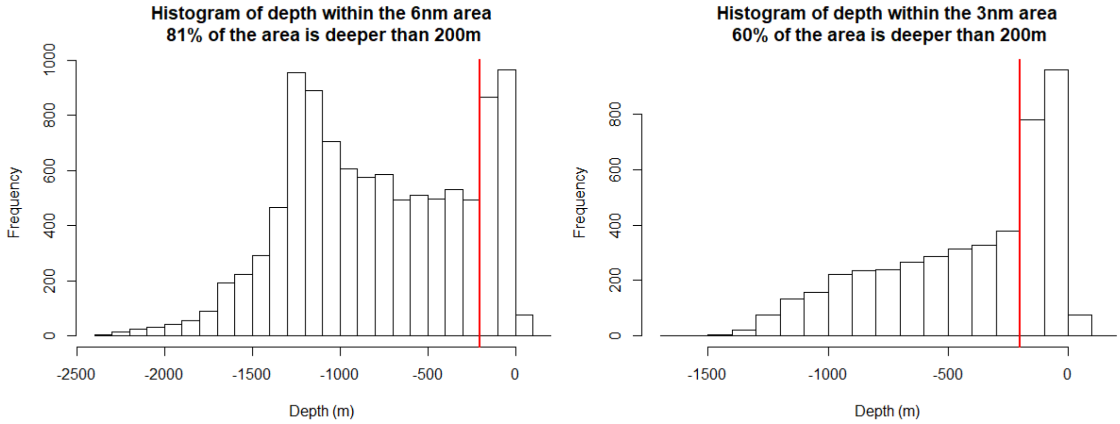


Figure 25. Histogram of the number of cells at each 100m depth strata within 3 nm and 6 nm from the island shores.

Based on the "science-based" principle, SCP should be based on the best available information gathered from all available sources and supported by the best available science-based evidence. A vast area of the Azores EEZ deeper than 2,500m has been poorly explored, and therefore the available scientific information is very limited (Figure 26). Most of the deep-sea benthic communities' studies, deep-sea fisheries surveys, deep-sea observers' databases, and consequently most of the deep-sea habitat suitability models, are limited to depths shallower than 2,500m. Even if areas beyond 2,500m depth can contain ecologically important ecosystems, essential habitats, or vulnerable species, the number of observations is likely insufficient, hampering the application of systematic conservation planning tools that could yield meaningful results. Indeed, the discrepancy in data availability and coverage would bias SCP results towards shallower areas, thus considering deeper areas as less important for achieving management goals, which may very likely not be the case.

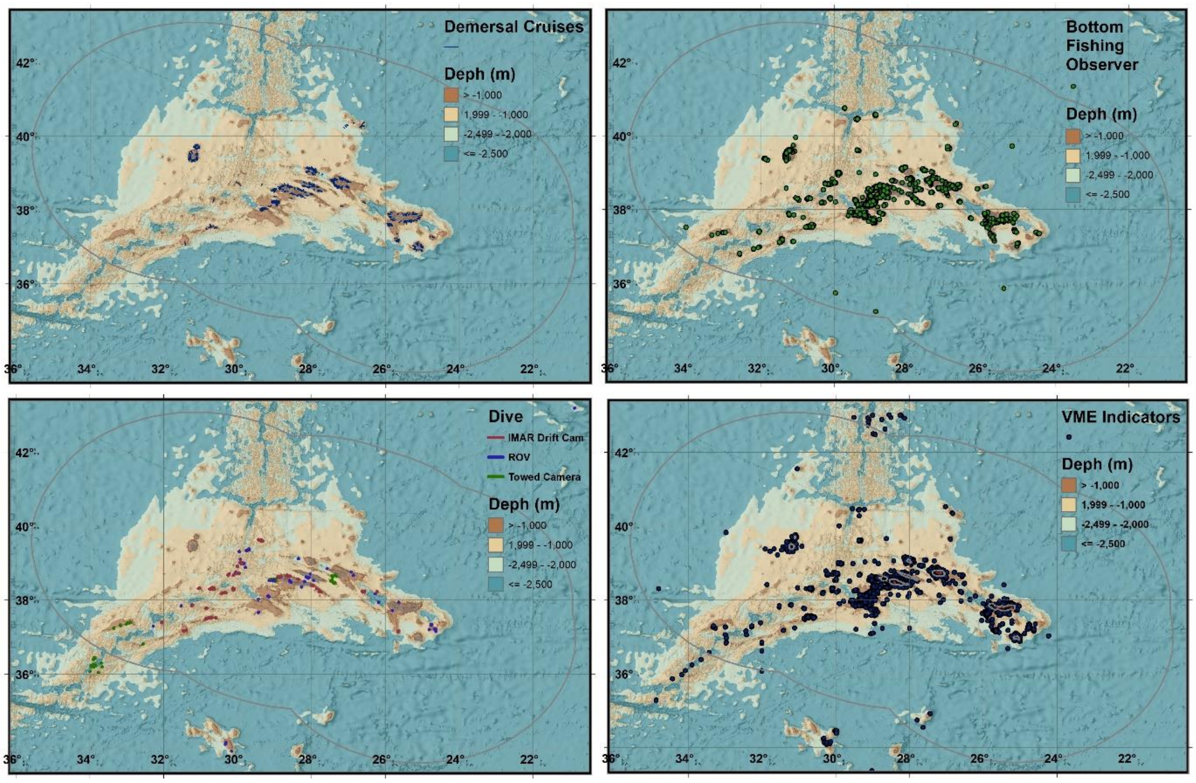


Figure 26. Summary of the deep-sea related scientific knowledge relevant to the systematic conservation planning approach for the deep Azores Region. Top left shows the location of the bottom fisheries research surveys; top right shows the commercial bottom fisheries events covered by observer's programs; bottom left shows the location of compiled video surveys; and bottom right shows the spatial distribution data of VME indicator records obtained from multiple sources.

4.2.1 "Science-based" principle

Based on the "***science-based***" principle the spatial planning area was divided into two sub-areas according to the data availability: a "***data-rich planning area***" shallower than 2,500m depth and a "***data-poor abyssal planning area***" deeper than 2,500m (Figure 27).

The "data-rich" spatial planning area was generally defined as the EEZ of the Azores shallower than 2,500m and beyond 6nm from islands shores. However, small enclaved patches of the Mid-Atlantic Ridge axis deeper than 2,500m were also included in the data-rich area since many of these areas have been intensively scientifically explored when compared with similar depths at abyssal plains. Additionally, these patches hold unique ecosystems such as hydrothermal vents with background fauna mostly composed of cold-water corals and sponge grounds; which may be considered as ecologically important areas to achieve some of the defined conservation goals. The final external data-rich spatial planning area boundary was obtained through the definition of a 2,500m depth contour using a simplification of the best bathymetry data available (Figure 27). The boundaries of the data-rich planning area were defined based on the following criteria:

- Considering the whole EZZ of the Azores and the best available bathymetry layers on the UTM zone 26N projection;
- Excluding a buffer of 6 nm around the island shores;
- Excluding those areas deeper than 2,500m except for deep areas in the Mid-Atlantic Ridge axis;
- Simplifying the bathymetry grid using the ArcGIS focal statistics with 30 neighbouring cells and reclassifying the cells into shallower and deeper than 2,500m;

- Converting the cells shallower than 2,500m into a simplified polygon which contain a minimum number of cells while remaining as close as possible the reclassified cells edges.

The "data-rich" spatial planning area represents about 319,175 km^2, whereas 0.02% being shallower than 200m, 1.21% between 200-600m, 1.41% between 600-800m, 6.48% between 800-1,200m, 82.11% between 1,200-2,500m and 8.77% > 2,500m.

The "data-poor abyssal" spatial planning area was generally defined as the area deeper than 2,500m beyond the limit of data-rich planning area external contour and until the limit of the EEZ of the Azores (Figure 27). The area known as Pico Sul, a seamount with a summit depth of about 1,200m depth (Rosa et al., 2016), was also included in the "data-poor abyssal" planning area since it is very isolated from all other shallow areas in the Azores and very few scientific data is available for the region. In fact, even the real bathymetry of this geological structure is not well resolved. The data-poor abyssal spatial planning area represents about 624,775 km^2, whereas 0.02% being shallower than 1,200m, 2.5% between 1,200-2,500m, 40.04% between 2,500-3,500m, 38.92% between 3,500-4,500m, 17.63% > 4,500m.

4.2.2 "Ecosystem-based approach" principle and the representativity and replication criteria

Based on the "***ecosystem-based approach***" principle, and the representativity and replication design criteria, the "data-rich" and "data-poor abyssal" spatial planning areas were further subdivided to ensure that the prioritization approach captures the latitudinal and longitudinal gradients of the deep marine ecosystem of the Azores and ensures replication within the spatial planning area. The two spatial planning areas were subdivided according to large geographical, geological and ecological boundaries.

The "data-rich" spatial planning area was subdivided into three regions encompassing 1) the area Western of the Mid Atlantic ridge, 2) the Mid-Atlantic Ridge, and 3) the area Eastern of the Mid Atlantic Ridge (Figure 27). The rationale for this subdivision lies on the fact that different water masses in the Western and Eastern part of the Azores EEZ influence the habitats, communities, and species occurring on both areas (Appendix 3). In addition, the MAR has been described as a potential ecological barrier for bathyal benthic megafauna species (Grebruk et al., 2010; Alt et al., 2019) potentially playing an important role in structuring the benthic communities occurring on both sides of the MAR. The "data-poor" area was also subdivided into the Western and the Eastern regions (Figure 27). Therefore, the spatial planting area is composed of 5 sub-regions; 3 in the "data-rich" area and 2 in the "data-poor" areas to ensure representativity of all potential deep-sea habitats and a local network replication (Figure 27).

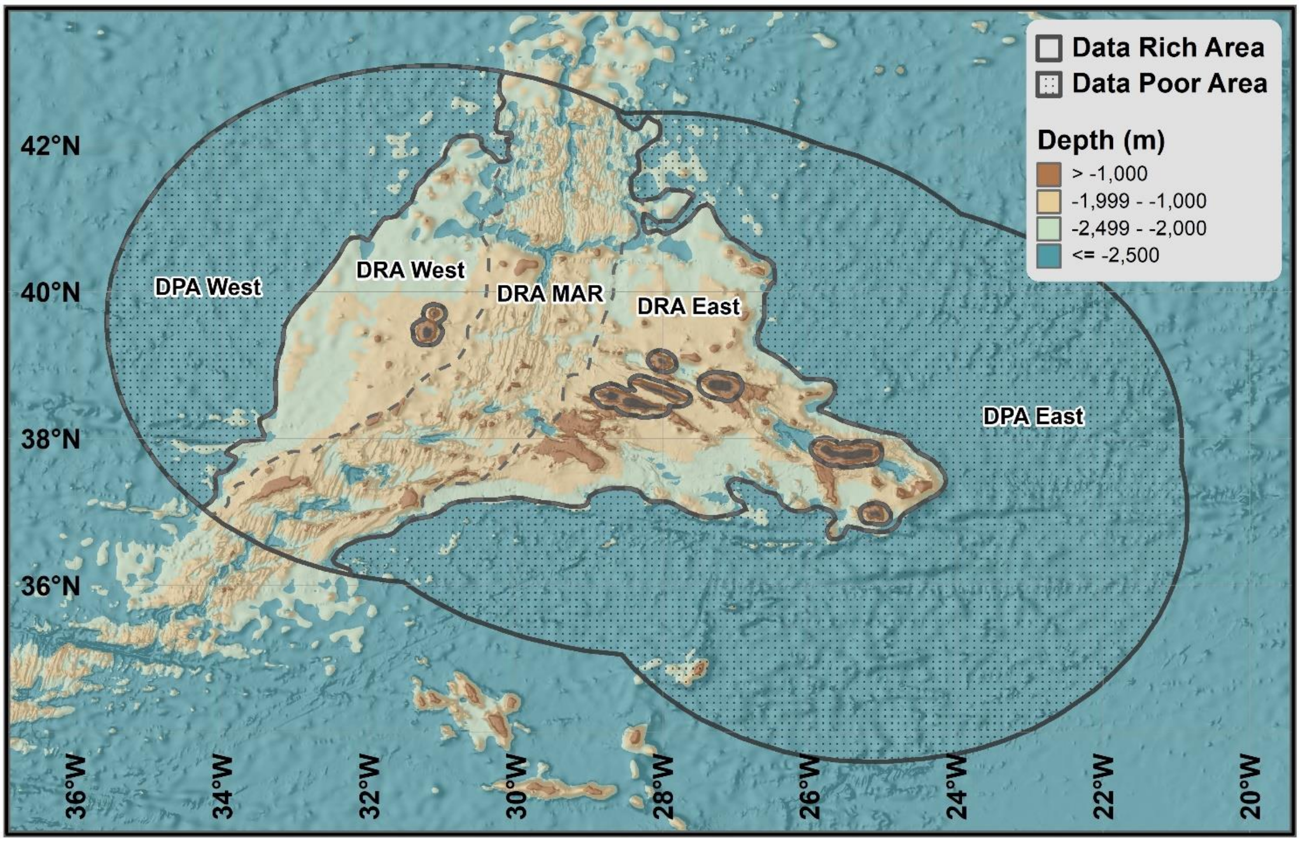


Figure 27. The spatial planning area considered in this systematic conservation planning approach was the deep sea of the Portuguese EEZ around the Azores archipelago; sometimes also referred to as the Azores EEZ. Based on the "science-based" principle the spatial planning area was divided into two sub-areas according to the data availability: a "data-rich planning area" shallower than 2,500m depth and a "data-poor abyssal planning area" deeper than 2,500m. Based on the "ecosystem-based approach" principle and the representativity and replication criteria the planning areas were subdivided into "data-rich West", "data-rich MAR" and "data-rich East", and "data-poor abyssal West" and "data-poor abyssal East".

4.3 Planning units

The spatial planning area was divided into planning units (PU, i.e. spatial cells) of a regular size. Since the spatial ecosystem food-web model used in the performance assessment was produced with 10km cells (Section 5.8.4), the PU size was set to 5km, representing a relatively high spatial resolution for offshore areas. This grid size originated a total of 12,767 PUs in the "data-rich spatial planning area" and 24,991 PUs in the "data-poor abyssal area" (Table 8). All geospatial layers were processed on the UTM26N coordinate reference system.

Table 8. Summary of the subregions delimited in the "data-rich" and "data-poor" planning areas to ensure the local replication of the prioritized networks.

Planning area	Subregion	N of PUs	% Spatial planning area	% "data-rich" area	% "data-poor" area
"Data-rich"	Western	2,862	8	22	
	MAR	5,079	13	40	
	Eastern	4,826	13	38	
"Data-poor"	Western	5,727	15		23
	Eastern	19,264	51		77
Total		37,758	100	100	100

5. Development of planning scenarios

The systematic conservation planning scenarios developed here considered a range of conservation features, representation targets, cost, boundary penalties (a proxy for size and number of conservation units), and constraints (e.g. existing area-based management rules). In this study, we present scenarios to address the overarching goals of restoring fish stocks of commercially important deep-sea benthic species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores EEZ. The main scenarios presented in this report aim to identify priority areas that provide the best compromise between all the management goals and objectives. However, this study also offers alternative scenarios to evaluate how different management goals and objectives can influence the prioritization outputs. These scenarios address the goals of 1) restoring fish stocks of commercially important deep-sea benthic species, or 2) ensuring the protection of intact and restoration of degraded Vulnerable Marine Ecosystems, and are presented as supplementary material.

5.1 Conservation features

One of the most important stages in SCP is the compilation of the best available data on biological and environmental conditions, as well as human uses, in the planning area. A particular focus should be given to collect information that would specifically address the agreed management goals and objectives. Also extremely important, is to identify the main knowledge gaps and to develop active efforts to fill those gaps. Several types of scientific information were included in the SCP approach for the Azores deep-sea to address the different management goals, objectives and design criteria (see Table 9).

To address the objectives related to the important resources (as described in the design criteria), we compiled the best available scientific data on several conservation features, such as the known occurrence and predicted distribution of commercially important benthic deep-sea fish (Parra et al., 2017), endangered or critically endangered deep-water sharks (Das et al., unpublished data), vulnerable cold-water coral species (Taranto et al., unpublished data), essential habitats (e.g. Santos et al., 2010; Menezes et al., 2012; Melo and Menezes, 2002), known VME indicators (COLETA database; multiple other sources), as well as with inferred indexes of VME likelihood (Morato et al., 2018).

To address the goals and objectives related to important areas, a selection of ecologically or biologically important areas were included in the SCP approach for the "data-rich" area. Among others, these areas include known shallow (<250m) and deep (>1400m) seamounts (Morato et al., 2008; 2013; Rodrigues et al., unpublished data), known near natural areas in the range of current deep-sea benthic fishing activities (< 1200m) (Morato et al., unpublished data), and known Vulnerable Marine Ecosystems (Morato, Carreiro-Silva, Dominguez-Carrió et al., unpublished data; Beaulieu & Szafranski, 2019). Finally, to address representativity design criteria and objectives, a habitat classification scheme based on Geomorphic Management Units (GMUs) and environmental conditions at the seafloor (Taranto, unpublished data) was also considered in the approach as conservation features. Existing area-based management tools (e.g. MPAs) were also considered in the planning approach. Finally, based on the "adaptive approach" principle, the SCP presented here should be adapted whenever new information is available.

Although biodiversity indices, such as species richness, were not used as conservation features, biodiversity hotspots-related objectives were also addressed in the prioritization solutions as we integrated multiple and diverse sources information regarding biological diversity (Figure 28). Indeed, prioritization algorithms tend to favour areas with higher species richness (proxies for biodiversity hotspots) since these areas provide a higher contribution to multiple objectives, fulfilling the representation targets of multiple features at the same time.

Based on the "science-based" principle, the spatial planning area was divided into "data-rich" and "data-poor abyssal" spatial planning areas (Section 4.2). Since most of the scientific information has its origin from a limited portion of the Azores EEZ, the conservation features described above were all used in the "data-rich" area, while only the habitat classification (i.e. GMUs and their sub-clusters) were considered in the "data-poor abyssal" area. Hence, various management objectives were addressed in the "data-rich" area, whereas only the habitat representativity objective was considered in the "data-poor abyssal" area.

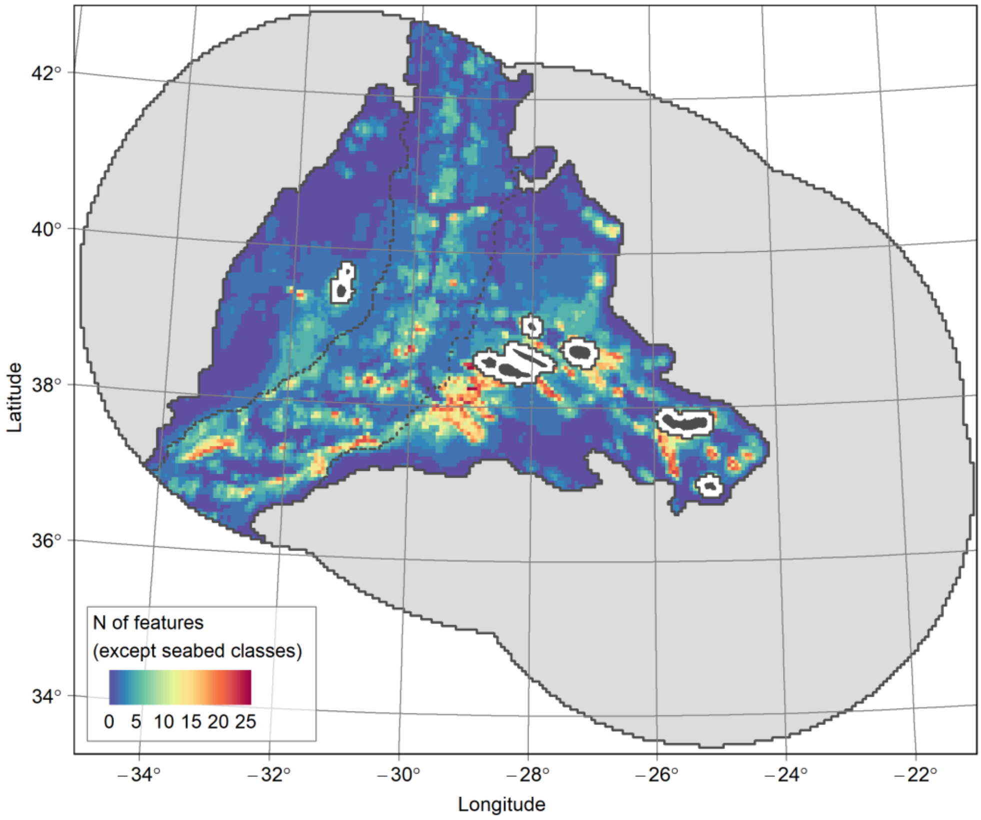


Figure 28. Number of features present in each planning unit (PU), excluding data regarding the Geomorphic Management Units (GMUs).

Table 9. Summary of the scientific information used to address management goals and objectives in the systematic conservation planning of the Azores deep sea.

Objectives	
• Ensure full protection (100%) of bona fide Vulnerable Marine Ecosystems by 2023	● (yellow)
• Protect at least 30% of known records of endemic, extremely long-lived, and reef engineers considered Vulnerable Marine Ecosystems indicators by 2023	● (light green)
• Protect at least 15% of inferred Vulnerable Marine Ecosystems by 2023	● (purple) ● (black) ● (brown)
• (food-web structure objectives)	?
• Protect a minimum of 75% of the known essential deep-sea habitats by 2023	NA
• Ensure the identification of keystone and foundation species by 2025	NA
• Protect a minimum of 30% of the known distribution of keystone and foundation species by 2028	NA
• (objectives for long-term maintenance of biologically mediated processes)	?
• (objectives for maintaining functional diversity of deep-sea ecosystems)	?
• Ensure no further loss of deep-sea biodiversity at ecologically relevant scales by 2030	● (red) ● (yellow) ● (light green) ● (green) ● (light blue) ● (blue) ● (pink) ● (purple) ● (grey) ● (black) ● (brown)
• Halt significant adverse impacts on vulnerable, endangered, or critically endangered species or habitats by 2030	● (red) ● (yellow) ● (light green) ● (light blue) ● (purple) ● (grey) ● (black) ● (brown)
• Protect a minimum of 75% of the known hotspots of biodiversity of deep-sea ecosystems by 2023	● (green)
• Protect 100% of the near-natural habitats within current fishing depths by 2023	● (light blue)
• Ensure at least 15% of all deep-sea benthic habitats and associated ecosystems are protected by 2023	● (blue) ● (brown)
• Ensure that the connectivity patterns, maximum larval dispersal distances and average annual movements of deep-sea foundation, keystone, vulnerable, and economically important deep-sea species are revealed by 2030	NA
• Ensure that maximum distances between the network units smaller than the 75th percentile of the median larval dispersal distances and average annual movements of mobile fauna by 2033	○
• (Resilience)	?
• Ensure the identification of areas with least climate hazards and climate-refugia for deep-sea biological diversity and commercially important deep-sea benthic fishes by 2025	NA
• Protect a minimum of 75% of the climate-resilient and climate-refugia areas by 2028	NA
• (objectives for maintaining healthy fish stocks)	?
• Rebuild fish stocks of commercially important deep-sea benthic species to levels prior to 1990 by 2040	● (red) ● (green) ● (light blue) ● (pink)
• Protect at least 15% of suitable habitat of commercially important deep-sea benthic fish species by 2023	● (pink) ● (brown)
• Ensure the identification of essential fish habitats of commercially important deep-sea demersal fish species by 2025	NA
• Protect at least 50% of essential fish habitats of commercially important deep-sea fish species by 2028	● (red)

Supporting scientific information

- ● (red) Known essential fish habitats (Santos et al., 2010; Menezes et al., 2012; Melo and Menezes, 2002)
- ● (yellow) Known Vulnerable Marine Ecosystems (Morato, Carreiro-Silva, Dominguez-Carrió et al., unpublished data; Beaulieu & Szafranski, 2019)
- ● (light green) Known occurrence records of selected Vulnerable Marine Ecosystems indicator taxa (endemic, extremely long-lived, and reef engineers) (COLETA database; multiple other sources)
- ● (green) Known shallow (<250m) and deep (>1500m) seamounts (Morato et al., 2008; 2013; Rodrigues et al., unpub. data)
- ● (light blue) Known near natural areas in the range of current deep-sea benthic fishing activities (< 1200m) (Morato et al., unpublished data)
- ● (blue) Geomorphic Management Units derived from the best-compiled bathymetry dataset (Gerald Taranto, unpublished data)
- ● (pink) Habitat suitability and abundance models of commercially important deep-sea benthic fish (Parra et al., 2017)
- ● (purple) Habitat suitability models of habitat-forming and vulnerable cold-water corals (Taranto et al., unpublished data)
- ● (grey) Habitat suitability models of endangered or critically endangered deep-water sharks and rays (Das et al., unpublished data)
- ● (black) Inferred Vulnerable Marine Ecosystems index (Morato et al., 2018)
- ● (brown) Existing area-based management tools (e.g. MPAs)
- ○ Other published sources

5.1.1 *Seabed habitats*

Analyses describing the environmental variability and the geomorphology of a region help to address the criteria of representativity in conservation planning. They are a mean to map environmental heterogeneity into distinct units each likely displaying a diversity of habitats and associated fauna. A systematic representation of areas presenting distinct environmental conditions into conservation solutions follows a precautionary approach. First, it allows for the inclusion of areas where little biological information is available. Second, it allows for the inclusion of areas that do not seem to be directly relevant to SCP goals, but that may be still relevant to maintain functioning and healthy ecosystems and, thus, indirectly serve SCP goals.

Geomorphic Management Units (GMUs) and the range of environmental conditions characterizing them were explored to identify potentially distinct seabed habitats. A total of nine Geomorphic Management Units were considered relevant for the Azores (Table 10). Bathymetry and bathymetric derivatives were used to assign seafloor areas to specific GMUs (Figure 29) (Taranto, unpublished data). Bathymetry data were compiled from different sources (Appendix 1.1.1) and bathymetry derivatives such as slope, coarse and fine Bathymetric Position Index (BPI) were calculated using the benthic terrain modeller (Walbridge et al., 2018) (Appendix 1.1.4). Coarse BPI served to describe large geomorphic features visible at a regional scale, and it was calculated using a large radius (500 km). Fine BPI aimed to describe secondary features of smaller scale and it was calculated using a smaller radius (10 km). GMUs were mapped in a three-step process. Initially, individual raster cells were combined into segments of relative homogeneous bathymetry following Geographic Object-Based Image Analysis (GEOBIA) principles (Blaschke et al., 2014). An *ex-novo* algorithm, which incorporated basic GEOBIA methodologies (Baatz et al., 2000; Drăguţ et al., 2010; 2014), was developed to automate this segmentation step (Gerald H. Taranto, unpublished data). An attribute table considering depth, slope, coarse and fine BPI was associated to each segment. Finally, a set of user-defined rules served to classify individual segments as particular GMUs considering both attribute thresholds and segment neighbourhood (Table 10).

Table 10. Geomorphic Management Units (GMUs) relevant for the Azores (regional scale) and criteria used for their classification. Simplified set of rules to define GMUs. Rules are applied in steps; for simplicity not every step is included in the table below. Seafloor areas (segments) are classified as a GMU based on three sets of criteria: they present characteristic attributes (Segment attributes) AND they neighbour specific GMUs (Adjacent GMUs) AND they share a minimum amount of border with these neighbours (Minimum Shared Border).

GMU	Segment attributes	Adjacent GMUs	Minimum Shared Border
Island Shelf (IS)	mean coarse BPI > 1000	Land	-
Island Shelf Unit (ISU)	mean coarse BPI > 400	IS	-
High Relief (HR)	mean coarse BPI > 1000	-	-
High Relief Unit (HRU)	mean coarse BPI > 200	HR	10-30%
Low Relief (LR)	mean coarse BPI > 700 & minimum BPI > 500	-	-
Low Relief Unit (LRU)	mean coarse BPI > 500 OR (mean coarse BPI > 200 AND mean slope > 5°)	LR	20%
Depression (D)	Minimum coarse BPI < -400 AND mean coarse BPI < 0	-	
Flat Areas (FA)	mean coarse BPI ≤ 200 AND mean slope ≤ 5°	-	
Hill and Lower slopes (HI)	mean coarse BPI > 200 AND mean slope > 5°		

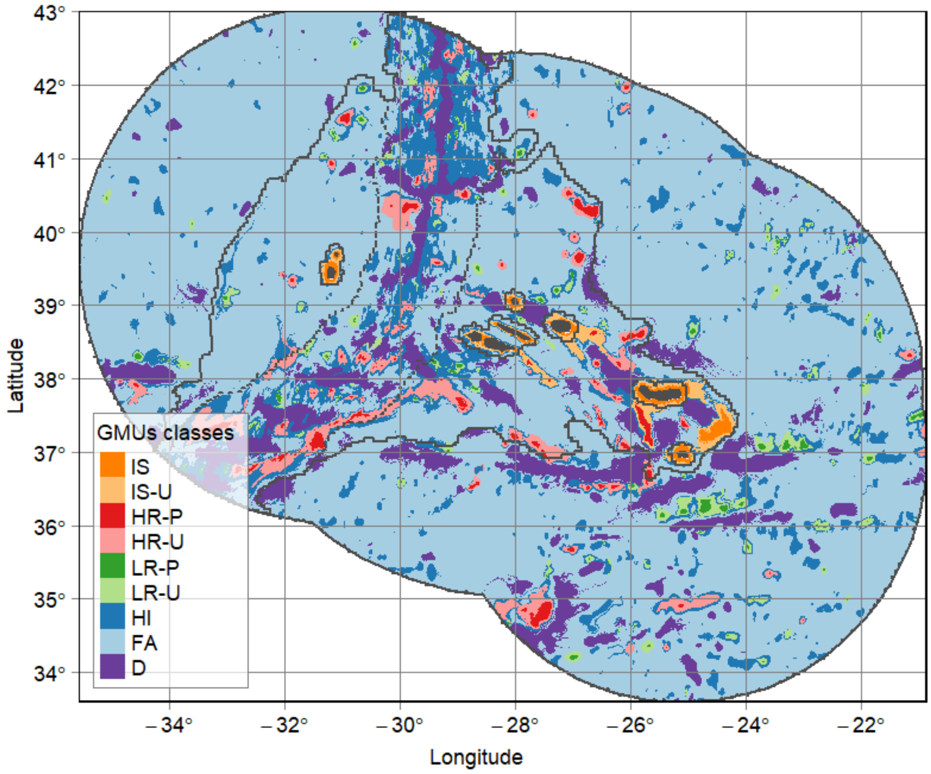


Figure 29. Geomorphic Management Units (GMUs) defined for the Azores EEZ (Taranto, unpublished data) using a multistep process. GMUs are defined in Table 10.

Different water masses can be characterized by different circulation patterns with important implications on biogeochemical and food regimes and, ultimately, on species survival. The influence of water masses on benthic communities has been reported in the scientific literature (e.g. Puerta et al., 2020). In the Azores, there are indications that the distribution of benthic communities may be affected by the geographic and bathymetric distribution of regional water masses (Taranto et al., unpublished data). Nutrient concentration (nitrate, phosphate, silicate, aragonite and calcite), oxygen saturation, temperature and particulate organic carbon fluxes are some of the environmental variables that typify distinct water masses in the Azores (Palma et al., 2012, Amorim et al., 2017). Here, we used these variables to subdivide each GMU into environmental clusters each potentially hosting a distinctive fauna. The clustering algorithm used was X-means, an extension of K-means that automatically estimates the optimal number of clusters (expected to match 'natural' data structures) using the Bayesian Information Criterion (Jain, 2010; Pelleg & Moore, 2000). The number of clusters could range from a minimum of two to a maximum of six for each GMU. Principal Component Analysis (PCA) was used to remove the high collinearity existing among nutrients. The first principal component (named "Nutrients PC1"), which explained 90% of the variance, was considered in the cluster analysis. Particulate organic carbon (POC) flux estimates were calculated based on Lutz et al. (2007) using the net primary production values reported in Amorim et al. (2017). The variables used and their sources are summarized in Table 11. By applying this clustering approach on the 9 GMUs defined in the Azores EEZ, a total of 31 clusters emerged, from 2 to 6 for each GMU (Figure 30). The environmental clusters varied in their environmental conditions at the seafloor (Table 12), highlighting the variety of water masses of the EEZ. As water masses are spatially structured according currents, depth and possible geographic boundaries (e.g., relief), the clusters of a same GMU could display different size, depth and geographical position (Table 12, Figure 30). For instance, most of the GMUs had clusters structured by depth (e.g. ISU with 3 clusters of median depth -454m, -839m and -1584m surrounding the islands), and some had a clear longitudinal or latitudinal structure (e.g. depressions with D_0 on the north, D_2 on the central south, and D_3 on the south-east; Table 12, Figure 30).

Table 11. Variable used to compute environmental clusters for each GMU.

Variable	Original resolution	Mean and SD	Units	Source
Temperature	0.05°	5.6 ± 2.5	°C	Böning et al., 2016
Aragonite	1°	1.33 ± 0.27	Ω	Morato et al., 2020
Calcite	1°	2.07 ± 0.43	Ω	Morato et al., 2020
Nitrate	1°	17.74 ± 1.90	µmol/l	Amorim et al., 2017
Phosphate	1°	1.14 ± 0.13	µmol/l	Amorim et al., 2017
Silicate	1°	12.64 ±1.85	µmol/l	Amorim et al., 2017
Oxygen Saturation	1°	79.40 ± 4.76	%	Amorim et al., 2017
Nutrient PCA	1°	3.01 ± 1.74	-	-
POC export	9 km	14.92 ± 1.52	mg C_{org} m^{-2} d^{-1}	-

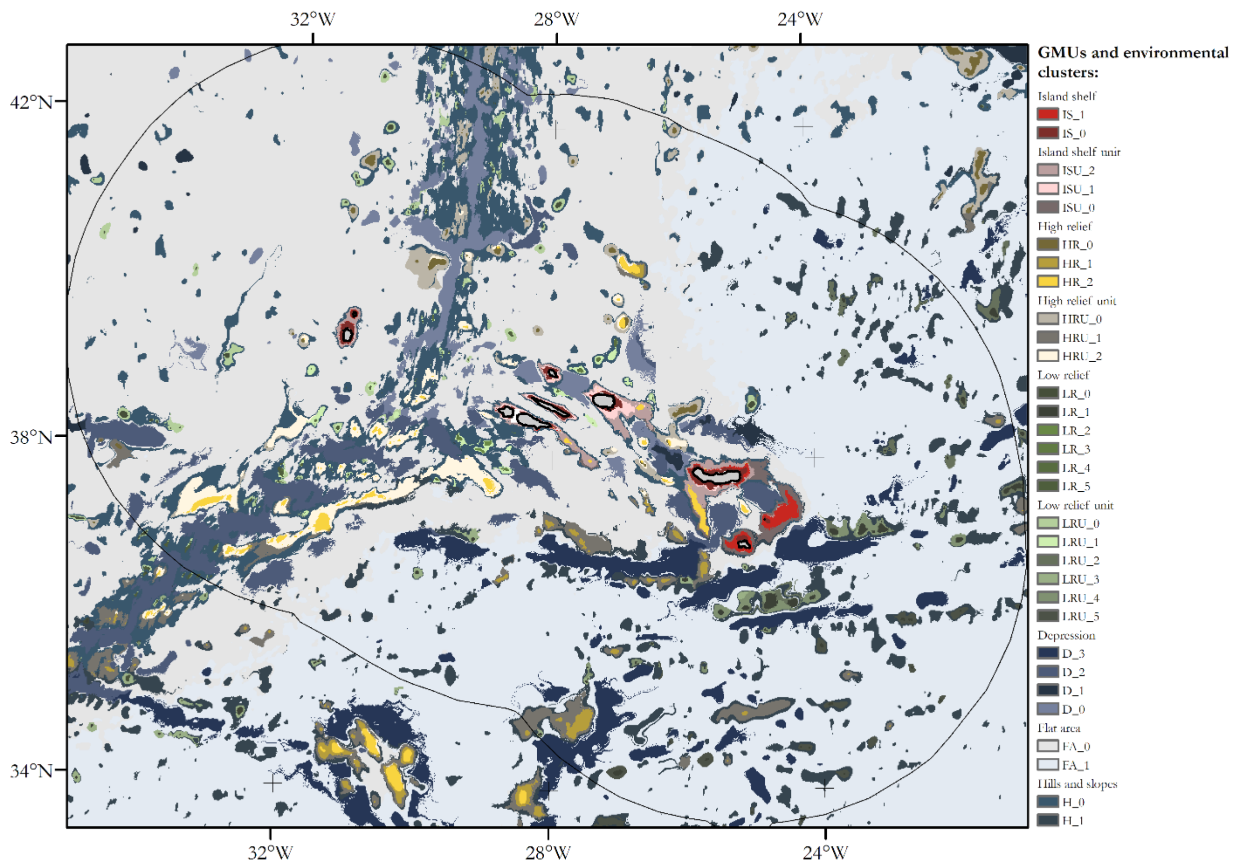


Figure 30. The 31 environmental clusters of the GMUs defined in the Azores EEZ.

Table 12. Description of the relative area, the depth and the environmental variables for each GMU cluster.

GMU legend	Cluster	Relative cover planning area (%)	Median depth (m)	Median temperature (°C)	Median Nutrients PC1	Median POC fluxes (mg Corg m-2 d-1)	Median oxygen saturation (%)
IS	0	0.01	144	14.39	14.01	15.80	94.49
IS	1	0.12	870	10.60	3.87	13.19	70.31
ISU	0	0.26	1,585	4.79	2.58	13.27	79.74
ISU	1	0.03	454	13.02	8.54	16.26	81.74
ISU	2	0.27	839	10.44	3.82	15.29	70.70
HR	0	0.13	1,742	3.64	2.33	16.06	80.46
HR	1	0.21	1,473	4.26	2.74	11.56	77.62
HR	2	0.32	646	9.88	5.75	13.25	73.99
HRU	0	0.79	1,511	4.03	2.44	16.43	79.17
HRU	1	1.06	2,157	3.44	1.93	12.07	79.81
HRU	2	1.21	1,058	8.40	3.32	13.94	71.94
LR	0	0.07	1,664	3.70	2.32	15.11	81.93
LR	1	0.18	3,059	2.25	-0.75	11.94	76.29
LR	2	0.01	281	11.03	12.23	14.91	89.25
LR	3	0.01	562	10.42	6.73	13.78	77.19
LR	4	0.02	852	9.17	3.57	16.19	69.60
LR	5	0.04	1,155	5.73	2.97	14.12	73.64
LRU	0	0.44	1,849	3.80	2.32	16.13	82.72
LRU	1	0.19	955	8.42	3.30	14.78	71.26
LRU	2	0.27	3,561	2.18	-1.54	13.13	74.85
LRU	3	0.08	2,516	2.84	0.96	11.82	80.00
LRU	4	0.29	3,255	2.22	-0.92	11.69	75.88
LRU	5	0.24	4,186	1.94	-2.55	10.67	74.57
D	0	2.28	2,426	3.63	1.90	16.52	83.09
D	1	0.26	4,094	2.28	-1.07	16.83	75.41
D	2	3.33	2,530	3.58	1.38	13.78	81.50
D	3	3.68	3,712	2.20	-1.68	11.56	75.11
FA	0	38.67	2,661	3.02	1.44	15.74	82.25
FA	1	35.04	3,829	2.22	-1.83	11.59	74.65
HI	0	6.45	1,810	3.93	2.36	15.58	81.27
HI	1	3.94	3,453	2.21	-1.21	11.80	75.26

GMUs were implemented in the prioritization approach as the relative cover of each GMU in each planning unit (i.e. each cell). As the GMUs covered all the planning area and were, by definition, mutually exclusive, the sum of the relative coverage all GMU in a given planning unit is always 1. Representation targets were set for all of the Geomorphic Management Units defined in the planning area to ensure that each of these habitats were captured at a sufficient level of representativity in conservation solutions, and to favour some of the GMUs because of their perceived higher ecological importance (Section 5.4.1). All the environmental clusters of a same GMU were given the target assigned to their GMU, thus the selection of planning units representing a GMU was spread in the same proportion between its different clusters. In order to prioritize simultaneously the GMUs for both areas and with different representation targets, the seabed layers were split according to the “data-rich” and “data-poor” extents, and then treated as different features in the prioritization software: 9 units for the “data-rich” area (IS, IS-U, HRP, HR-U, LRP, LR-U, D, HI and FA), 6 units for the “data-poor” area (HRP, HR-U, LRP, LR-U, D and HI).

5.1.2 Commercially important deep-sea benthic fish species

The spatial distribution of mobile deep-sea fishes benthic is largely driven by the spatial distribution of their suitable habitats (Menezes et al., 2006), which are usually persistent through time (Mahon, & Smith, 1989). These spatial patterns are better understood through dedicated field surveys, however, research cruises dedicated to the study of commercially important fish stocks in the Azores are biased towards island slopes and only a few offshore fishing grounds (Figure 26). Therefore, alternative sources of information that could help in predicting the suitable habitat of commercial important deep-sea fishes in the whole spatial planning area are necessary. In recent years, different types of modelling tools have been used to predict the suitable habitat of commercially important fishes (Jones et al., 2012; Gomez et al., 2015; Parra et al., 2017) and even to determine likely essential fish habitats (Laman et al., 2018). Hence, the predictive modelling of deep-sea fish distribution in the Azores was considered the most suitable method to address the management objectives related to the protection of the suitable habitat of commercially important deep-sea benthic fishes and to rebuild their stocks.

Habitat suitability models for six of the most important commercially important deep-sea benthic fishes occurring in the spatial planning area were included in the prioritization approach (Parra et al., 2017; Appendix 1.3.7). These species were: “*alfonsins*” or alfonsinos (*Beryx decadactylus*, and *Beryx splendens*), “*boca-negra*” or blackbelly rosefish (*Helicolenus dactylopterus*), “*goraz*” or blackspot seabream (*Pagellus bogaraveo*), “*cherne*” or wreckfish (*Polyprion americanus*), and “*bagre*”, “*cântaro*” or offshore rockfish (*Pontinus kuhlii*). Habitat suitability models were also available for “*abrótea*” or forkbeard (*Phycis phycis*) and “*pargo*” or red porgy (*Pagrus pagrus*) but were not included in the prioritization approach since the vast majority of their predicted distribution lies outside the planning area (i.e. within 6nm miles from island shores).

The habitat suitability index of those cells where species were predicted to be present (i.e. above a certain threshold; Parra et al., 2017), was used in the prioritization approach (Figure 31). Since the model predictions were presented at a grid size of about 300x300m, average habitat suitability values were calculated for each species in each of the 5x5km PUs (i.e. cells). Parra et al. (2017) also predicted the spatial distributions of the relative abundance of five species of interest (*B. decadactylus*, *B. splendens*, *H. dactylopterus*, *P. bogaraveo*, *P. kuhlii*), but these were not used in the prioritization approach because of the high uncertainty of these estimates. However, we used these predictions in the performance assessments by using the sum of the predicted abundances within each PU.

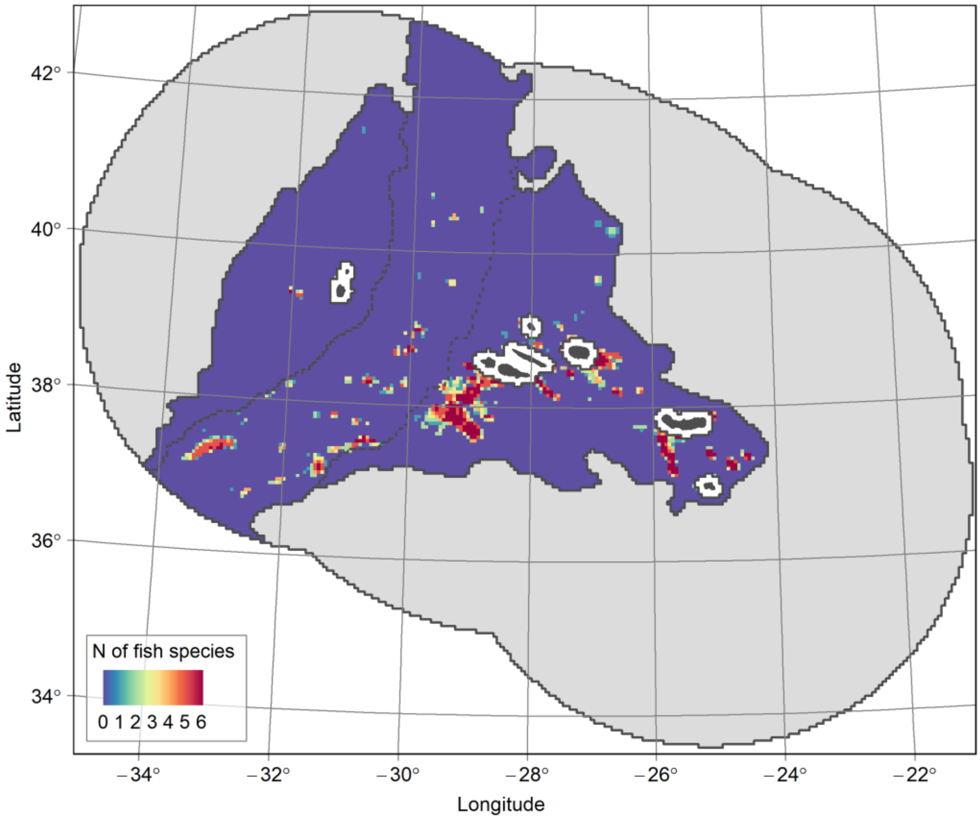


Figure 31. Distribution of commercially important deep-sea fish species richness as predicted by the habitat suitability models developed for six species in the Azores (Parra et al., 2017). No habitat suitability predictions were available for the "data-poor" area.

5.1.3 Vulnerable deep-sea sharks and rays

Deep-water sharks and rays are generally considered particularly vulnerable to fishing because of their extremely low productivity (Rigby & Simpfendorfer, 2015) and their likelihood of being accidentally bycaught in bottom deep-sea fisheries (Pham et al., 2013; Fauconnet et al., 2019a). Recently, discards from the Azores deep-sea fishery were described of concern since they include many deep-water sharks and rays listed as "endangered" or "critically endangered" in the IUCN European Red List of Threatened Species (Nieto et al., 2017; Table 13). Because of this perceived vulnerability, the EU Common Fisheries Policy adopted a zero total allowable catches for deep-water sharks in 2010 (EC Reg. 1359/2008) and moved them to the list of "prohibited species" in 2019 (EC Reg. 2025/2018). Despite these regulations, deep-water sharks and rays are still regularly, though occasionally, taken as bycatch of bottom longlining and drifting deep-water longlining (Fauconnet et al., 2019b, Table 13). Contrary to the general perception that most of these species are of conservation concern, most Azorean fishers consider that the abundance of deep-water sharks has remained stable at high levels over the last decade (Fauconnet et al., 2019b). No studies have yet evaluated the status of deep-water sharks in the Azores, but the new research project SosTubaProf (MAR2020-16-01-03-FMP-0040), starting in 2020, will address some of these questions in close collaboration with fishers and other stakeholders.

Table 13. Elasmobranch species included in the prioritization approach. The vulnerability status (Nieto et al., 2017) and habitat suitability models available (Das et al., unpublished data) are shown. IUCN refers to the species status on the IUCN Red List of Threatened Species for Europe from the latest assessment: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NA = Not Evaluated (global status given in parenthesis) from the latest assessment.

Species	IUCN	Fishing prohibition	Bycatch	Habitat suitability model	Abundance model
Centrophorus squamosus	EN	Y	Y	Y	
Centroscymnus coelolepis	EN	Y		Y	
Centroscymnus owstonii	NA (VU)		Y	Y	
Centroselachus crepidater	LC	Y	Y	Y	
Dalatias licha	EN	Y	Y	Y	
Deania calcea	EN	Y	Y	Y	Y
Deania profundorum	DD		Y	Y	Y
Dipturus batis	CR	Y		Y	
Etmopterus pusillus	DD		Y	Y	Y
Etmopterus spinax	NT	Y	Y	Y	Y
Leucoraja fullonica	VU			Y	
Squaliolus laticaudus	LC			Y	

Similar to commercially important deep-sea fishes, predictive habitat suitability modelling of vulnerable deep-sea sharks and rays in the Azores was considered the most suitable method to address the management goals and objectives related with the protection of vulnerable, endangered, or critically endangered species, but also the goal of maintaining the biological diversity of deep-sea ecosystems. Habitat suitability models for 12 species of deep-water sharks and rays occurring in the spatial planning area were included in the prioritization approach (Das et al., unpublished data; Appendix 1.3.6). The species were selected according to their occurrence in the planning area, their conservation status and vulnerability, and included 10 sharks (*Centrophorus squamosus, Centroscymnus coelolepis, Centroscymnus owstonii, Centroselachus crepidater, Dalatias licha, Deania calcea, Deania profundorum, Etmopterus pusillus, Etmopterus spinax* and *Squaliolus laticaudus*) and two rays (*Dipturus intermedia* cf. *batis* and *Leucoraja fullonica*).

The habitat suitability index of those cells where the species were predicted to be present (i.e. above a certain threshold; Das et al., unpublished data), was used in the prioritization approach. Since the model predictions were presented on a grid size of about 1200x1200m, the average habitat suitability index was calculated for each species in each 5x5km PU (i.e. cells). Das et al., (unpublished data) also predicted the spatial distribution of the relative abundance of four species of interest, namely *Deania calcea*, *Deania profundorum*, *Etmopterus pusillus*, and *Etmopterus spinax*. These abundance predictions were not used in the prioritization approach because of the lack of confidence on these estimates, but were used in the performance assessments using the sum of predicted abundances within each PU.

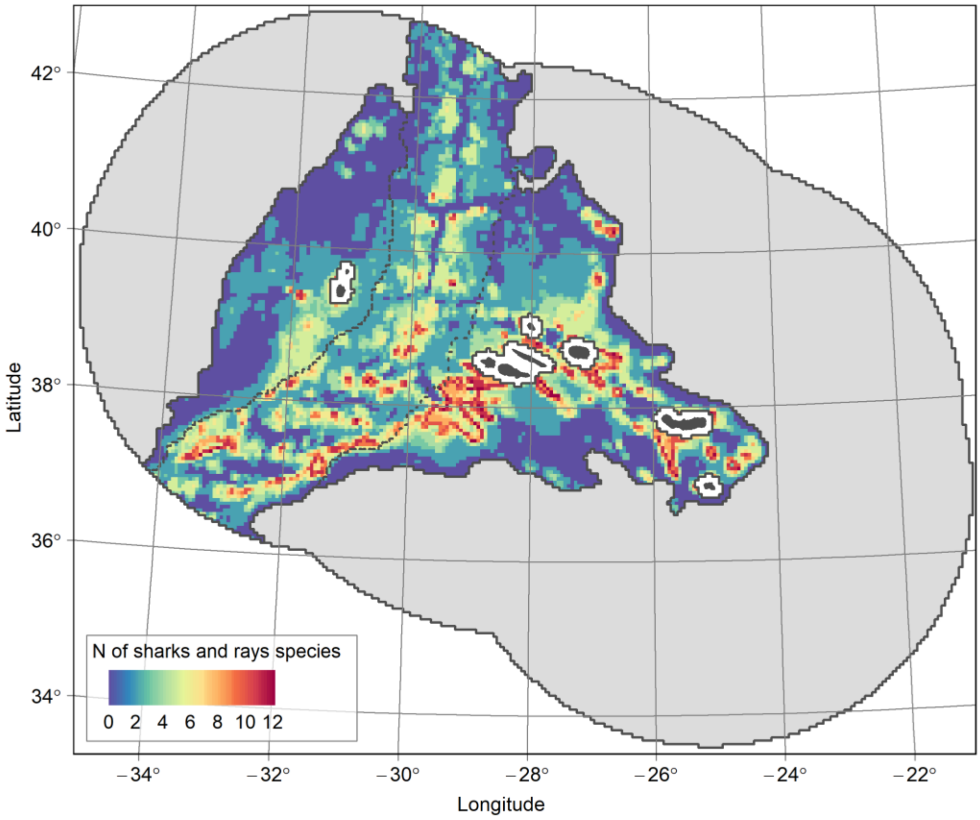


Figure 32. Distribution of the vulnerable deep-sea sharks and rays species richness in each planning unit as predicted by habitat suitability models developed for 12 species in the Azores (Das et al., unpublished data). No habitat suitability predictions were available for the "data-poor" area.

5.1.4 Habitat-structuring cold-water corals

As described above (Section 2.1.3), the Azores is considered a hotspot for cold-water corals in the North Atlantic, with over 200 species identified to date (Braga-Henriques et al., 2013; Sampaio et al., 2019a; ATLAS, unpublished data) and more than 20 different types of coral gardens (Tempera et al., 2013; ATLAS, unpublished data). These coral gardens are used by a large number of associated sessile (e.g. zoantharians, anemones, hydroids) and vagile species (e.g. polychaetes, echinoderms, crustaceans, fish) (Braga-Henriques et al., 2011, 2012; Pham et al., 2015; Carreiro-Silva et al., 2017; Gomes-Pereira et al., 2017; Porteiro et al., 2013) and therefore are considered important structuring habitats. Some of the cold-water species present in the Azores are slow-growing, long-lived and have low reproductive outputs, which makes them extremely vulnerable to fisheries or other human impacts, with recovery times of individual coral colonies and communities from decades to centuries (Clark et al., 2019). These characteristics have resulted in some coral habitats being listed as Vulnerable Marine Ecosystems (VME) (UNGA, 2007; OSPAR 2009, 2010c,d). Cold-water coral species of the order Antipatharia (e.g. black corals *Leiopathes* spp., *Bathypathes* spp.), Scleractinia (e.g. reef-building corals *Lophelia pertusa* and *Madrepora oculata*) and family Stylasteridae (e.g. *Errina* spp., *Stylaster* spp.) are listed under the Appendix II of the CITES convention. In addition, communities formed by cold-water corals and sponges are listed on the OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR, 2009; 2010 a,b,c,d).

The use of habitat suitability modelling of selected habitat-structuring cold-water corals in the Azores was considered appropriated to address the management goals and objectives related with ensuring the protection of vulnerable, endangered, or critically endangered species, and with ensuring the protection of VMEs, but also with the goal of maintaining the biological diversity of deep-sea ecosystems. Habitat suitability models have been developed for several important habitat-structuring cold-water corals for which sufficient information was available to model their distributions at the scale of the Azores EEZ (Taranto et al., unpublished data; Appendix 1.3.5). Models outputs were produced as maps of suitable habitats with three levels of confidence (high, medium, and low), resulting from the comparison of different modelling approaches (fuzzy matching of GAM and Maxent habitat suitability predictions) and the sensitivity of model outputs to initial conditions (bootstrapping). Here, we used a subset of the fifteen habitat suitability models developed for cold-water corals (Taranto et al., unpublished data; Figure 33). Model outputs for *Callogorgia verticillata*, *Paracalyptrophora josephinae* and *Paragorgia johnsoni* were used in the prioritization approach because of their important role as ecosystem engineers, forming sometimes large, extensive and complex habitats. *Dentomuricea* aff. *meteor* and *Viminella flagellum* are known to form complex coral-gardens that support a wide, but not fully known, variety of species and ecosystem functions. To capture this aspect, model outputs of these two species were combined and used in the prioritization approach only in areas where they co-occur.

Instead of using the habitat suitability index in the prioritization approach, as for commercial fishes and elasmobranchs, here we used the level of confidence in the presence of suitable habitat (0= absence, 1= low, 2= medium, 3= high) of these 3 taxa to prioritize areas with the higher confidence. This was implemented by estimating the average confidence level of the predicted presence at a 1.2x1.2km resolution, in each 5x5km PU. For the coral garden (*Dentomuricea* aff. *meteor* and *Viminella flagellum*), the average confidence levels were calculated only for PUs where these species were predicted to co-occur.

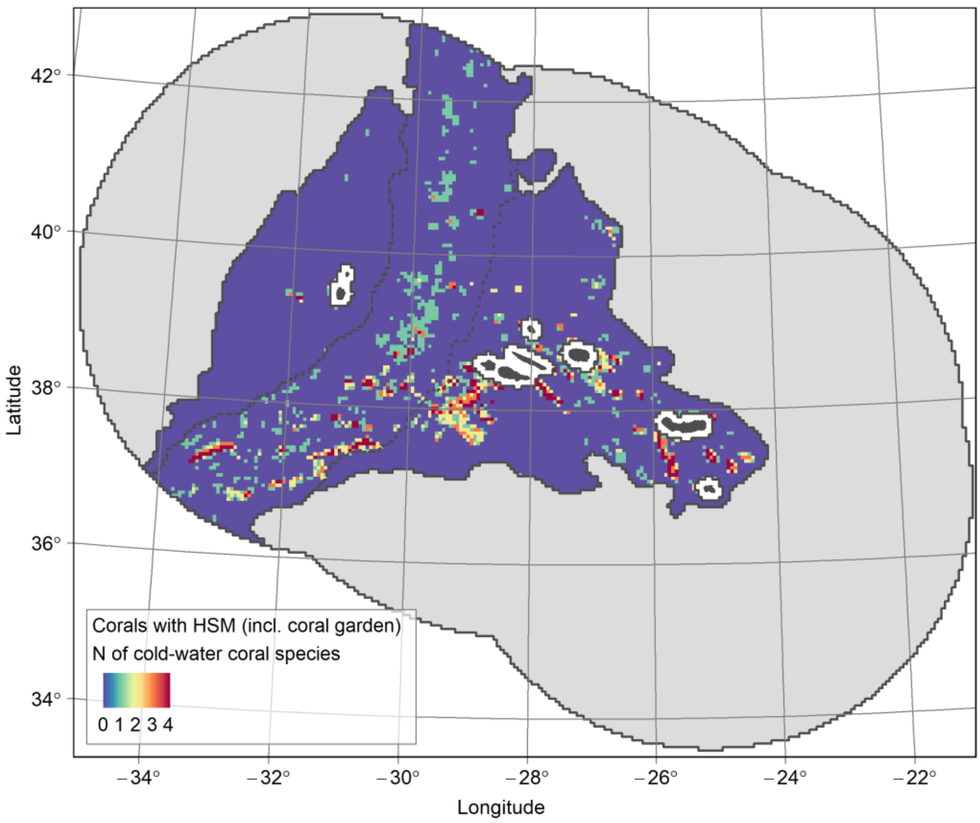


Figure 33. Distribution of the habitat-structuring cold-water coral species richness as predicted by habitat suitability models in the Azores (Taranto et al., unpublished data). The coral garden feature of co-occurring *Dentomuricea* aff. *meteor* and *Viminella flagellum* is considered here as one "species". No habitat suitability predictions were available for the "data-poor" area.

Four additional cold-water coral species were considered in the prioritization approach for being unique or rare, fragile, structurally important, or for having life-histories that make recovery difficult. *Errina dabneyi* is an endemic species of the Azores region and very sensitive to physical impact. *Leiopathes* spp. are exceptionally long-lived organisms (up to 4,000 years) with extremely low growth rates and very vulnerable to fisheries impacts (Carreiro-Silva et al., 2013; Roark et al., 2009). *Lophelia pertusa* and *Madrepora oculata* are not reef engineers in the Azores region, but, similarly to many hydrothermal vent species (Breusing et al., 2016), this region is expected to have a major role in connecting the east and west Atlantic populations. Because the occurrence of these species displays a very patchy distribution (Orejas et al., 2009), it is likely that the habitat suitability models, although correctly capturing the species ecological niches, may over-predict their distributions. Hence, instead of the habitat suitability predictions, we used known occurrences of living colonies of these four species from the IMAR databases (COLETA, video surveys, and observer databases), along with known locations of *Errina dabneyi* aggregations (Figure 34).

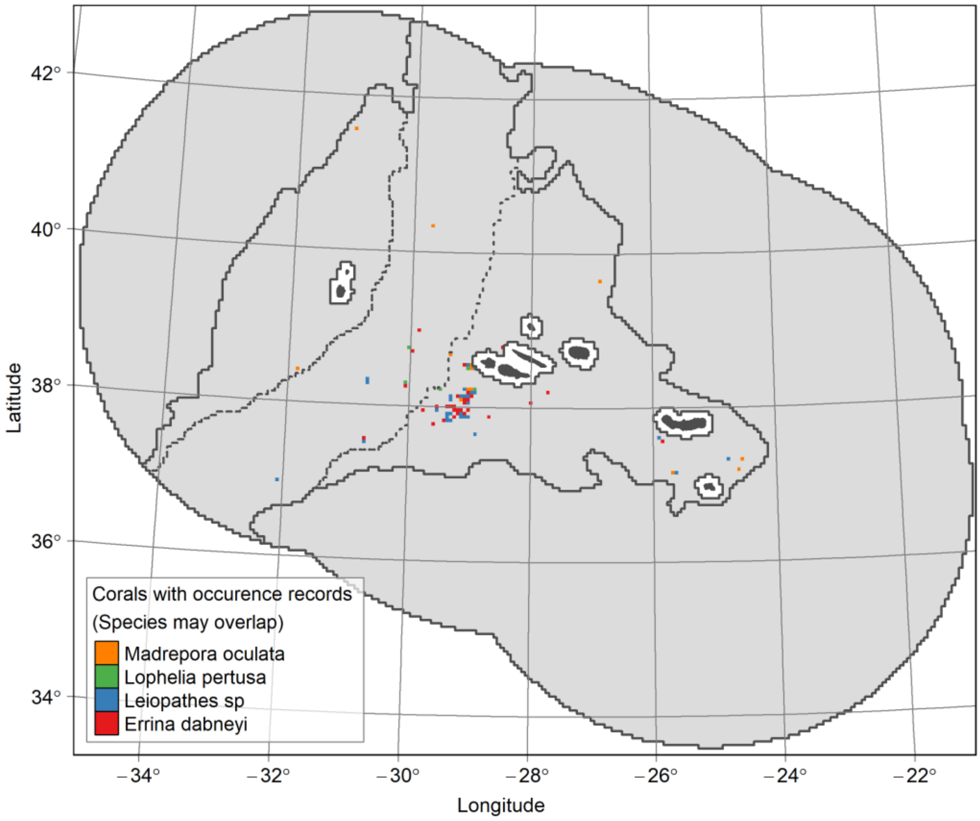


Figure 34. Known occurrences of living colonies of unique or rare, fragile, structural important, or vulnerable cold-water coral taxa from the IMAR databases (COLETA, video surveys, and observer databases).

5.1.5 Inferred Vulnerable Marine Ecosystems

Recognizing the vulnerability of deep-sea biodiversity, the United Nations General Assembly (UNGA) called upon States and Regional Fisheries Management Organizations (RFMOs) to identify areas where Vulnerable Marine Ecosystems (VME) occur, or are likely to occur, and to prevent significant adverse impacts (UNGA, 2006). The Food and Agricultural Organization (FAO) of the United Nations subsequently developed criteria for defining what constitutes a VME (FAO, 2009; 2016):

- ***Uniqueness or rarity:*** an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include: habitats that contain endemic species, habitats of rare, threatened or endangered species that occur only in discrete areas nurseries or discrete feeding, breeding, or spawning areas;
- ***Functional significance of the habitat:*** discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species;
- ***Fragility:*** an ecosystem that is highly susceptible to degradation by anthropogenic activities;
- ***Life-history traits of component species that makes recovery difficult:*** ecosystems that are characterised by populations or assemblages of species with one or more of the following characteristics: slow growth rates, late age of maturity, low or unpredictable recruitment, and/or longlived;
- ***Structural complexity:*** an ecosystem that is characterised by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.

These criteria may apply to a wide variety of habitats and ecosystems of the deep-sea (e.g. hydrothermal vents, seamounts or cold seeps). Whilst significant steps have been made to map and protect VMEs in the high-seas in general (e.g. Portela et al., 2010) and in the high-seas regulated by RFMOs (e.g. Durán-Muñoz et al., 2012a), progress has been inconsistent or incomplete, mainly in national waters (Durán-Muñoz and Sayago-Gil, 2011; FAO, 2016). VMEs have been identified based on the occurrence of indicator taxa such as stony or gorgonian corals, or sponges, and are therefore best identified using high-quality underwater imagery, allowing an accurate and quantitative description of community composition and associated fauna (e.g., ICES, 2016, 2017; Section 5.1.6). However, observations are only available for a tiny fraction of the deep sea, hampering the trigger of management actions (Ardron et al., 2014). With rapid advances in video-survey technology (e.g. Dominguez-Carrió; unpublished data), much more of the seafloor will become known in the coming years. But currently, large amounts of data on VME indicator taxa occurrences are available across large spatial scales, including the Azores (e.g. COLETA database). Taking advantage of existing databases, Morato et al. (2018) developed a multi-criterion assessment method to infer areas that may constitute a VME with varying degrees of confidence.

Information on inferred locations of VMEs was considered relevant to address the management objectives related to the protection of VMEs, protection of vulnerable, endangered, or critically endangered species or habitats, and maintain the biological diversity of deep-sea ecosystems. Acknowledging that the available data does not cover the full deep sea areas of the Azores, we used georeferenced data on VME indicator taxa to estimate a VME index (described in Morato et al., 2018) along with a confidence index. VME indicators' occurrence data was originated from the IMAR databases on VME indicator species (COLETA, video surveys, and observer databases), along with new data originated from deep-sea exploration conducted under the ATLAS H2020 (No 678760) and PO2020 MapGES (Acores-01-0145-FEDER-000056), among other projects and expedition (e.g. Blue Azores Expedition 2018). The multi-criterion assessment method (Morato et al., 2018) was implemented on the prioritisation approach by assigning the VME index to the PUs and by giving higher representation targets for PUs with higher VME index (Figure 35; Appendix 1.3.9). A VME index value was assigned to only 2.22% of the "data-rich" area, while for the other 97.78% no information on VME indicators is currently available. Known hydrothermal vents are considered *bona fide* VMEs (FAO, 2009; Van Dover et al., 2018), while some seamounts may also qualify as such (Watling & Auster, 2017). These two types of bona fide VMEs were addressed in the Sections about Important areas (Section 5.1.6 and 5.1.7).

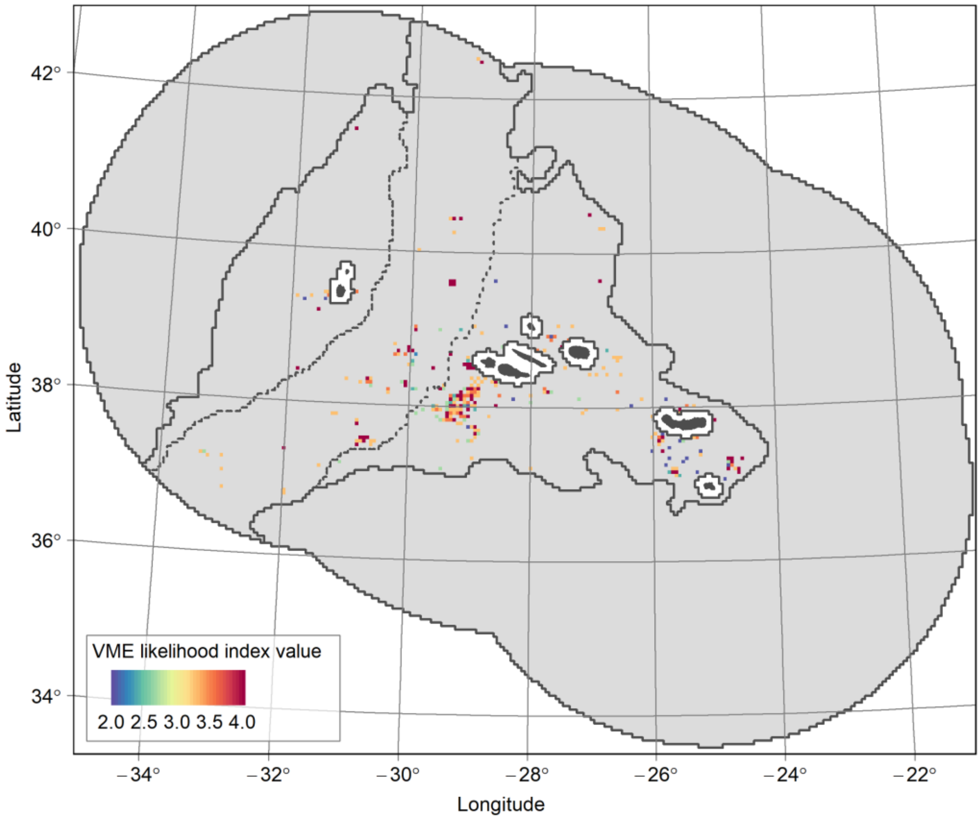


Figure 35. VME index as measured by the multi-criterion assessment method (Morato et al., 2018) applied to the planning units in the Azores EEZ.

5.1.6 Important areas: known VMEs including hydrothermal vents

Unequivocal VMEs were defined as areas that have been scientifically explored, described, and that meet the FAO criteria (FAO, 2009) for defining Vulnerable Marine Ecosystems (Section 5.1.5). Unequivocal VMEs were identified based on these criteria through analysis of video transects recorded during exploration cruises. They consisted of known hydrothermal vents and, particularly, vulnerable benthic communities, which is mostly consisted of cold-water corals and sponge aggregations.

Hydrothermal vents in the Azores deep-sea

Hydrothermal vent fields are recognized as important VMEs (FAO, 2009; Van Dover et al., 2018) in the Azores, region with six known vent fields located along the MAR (Beaulieu & Szafranski, 2019, Figure 2; Appendix 1.1.3). These are: 1) Menez-Gwen including Bubbylon, 2) Lucky Strike including Ewan, 3) Menez Hom, 4) Saldanha, and 5) Luso, as well as 6) the Rainbow vent field in the claimed Extended Continental Shelf. Dom João de Castro is a shallow-water hydrothermal vent associated with the hyper-slow spreading Terceira Rift. These hydrothermal vent fields exhibit a wide range of environmental conditions (Table 1), including depth and associated physical parameters, and different geologic settings and underlying rocks, fluid chemistry and faunal assemblages (Figure 3), with high endemic rates and thus high intrinsic natural value (as described in Section 2.1.3). All confirmed active vent fields are MPAs under the Marine Park of the Azores (see Section 2.3.2). Information on these features used in the prioritization approach (Figure 36) was obtained from the InterRidge Global Database of Active Submarine Hydrothermal Vent Fields (Beaulieu & Szafranski, 2019; Appendix 1.1.3).

Ten hydrothermal vent areas located inside the planning area were considered in the prioritization approach as important areas. This were Saldanha, Famous, Lucky Strike, Menez Hom and South Lucky Strike, Menez Gwen and Bubbylon, Luso, Don João de Castro, and the inferred South Kurchatov. The presence of hydrothermal vents was extracted in PUs. Whereas 3 PUs contained inferred vents only (not yet explored and confirmed), these were kept following the "precautionary approach" principle.

Vulnerable Marine Ecosystem indicator biological communities in the Azores deep sea

Recent developments in robotics and imaging technology have provided new opportunities to study the ecology of benthic species and communities. During the last decade, IMAR has led or participated in several oceanographic surveys that make use of underwater images to better understand the diversity and distribution of deep-sea benthic fauna along 25 underwater features across the Azores EEZ (Figure 36). The spatial extent of the video transects carried out is vast and covers a large number of seamounts, ridges and slopes between 100 and 1500 m depth. The largest sampling effort until now has been placed in the Mid-Atlantic Ridge, where 18 features have now been inspected, including 6 seamounts/ridges that belong to the Gigante Seamount Complex. More than 130 dives have now been successfully completed along the MAR covering a depth range of 180-1500 m. The islands that belong to the central group have also been thoroughly explored, with more than 50 dives in 9 seamounts and island slopes located in their close proximity, covering depths of 100-1300 m. Finally, only 3 features have been investigated around the islands of the eastern group, with just over 15 dives covering depths of 350-1500 m. In august 2019, and as a results of the collaboration with the Blue Azores program and with the Fundação Rebikoff-Niggeler (FRN), we have explore the never surveyed seamount ridge Baixo de São Mateus with the FRN's submersible LULA1000. In this survey we characterizes the diversity and spatial distribution patterns of benthic communities and commercial fishes in this important fishing ground. We also evaluated if this area may fit the FAO criteria that defines what constitutes a Vulnerable Marine Ecosystem. The list of benthic communities identified from the video images in these features is provided in Table 14. For a brief description of the diversity of the benthic communities identified in each feature, see Appendix 3. The detailed report of the submersible LULA surveys in Baixo São Mateus is presented in Appendix 4.

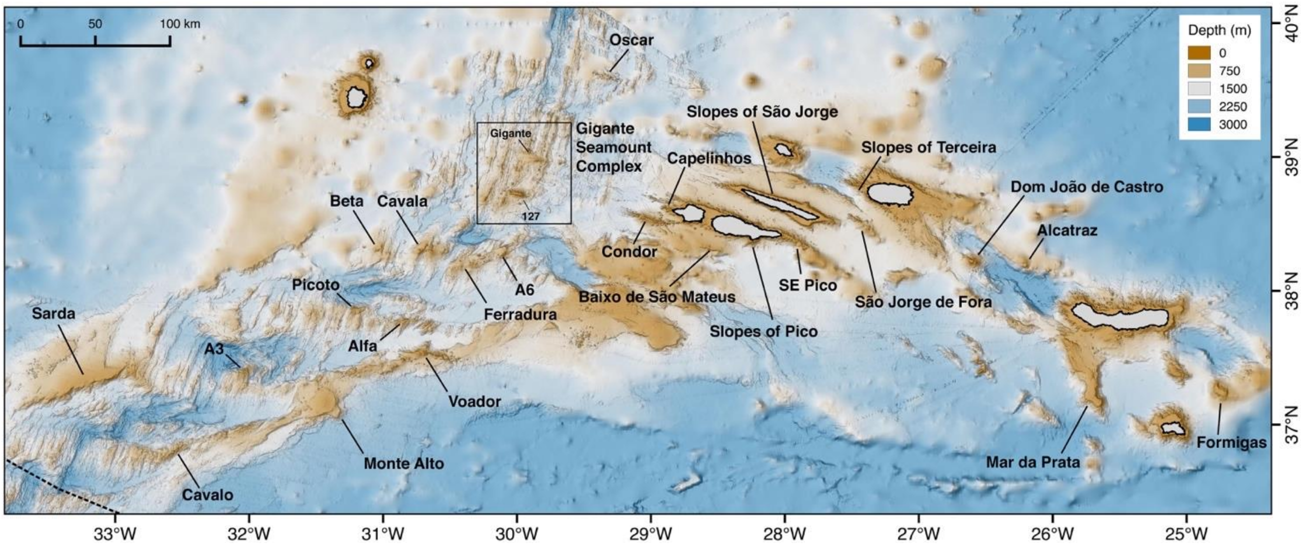


Figure 36. Location of the underwater features that have been visually investigated by means of ROVs, tow cams and manned submersibles across the Azores EEZ in the last decade.

Based on the video footage evaluated so far, the deep-sea areas of the Azores should be regarded as very diverse ecosystems, home to a large number of megabenthic species (Figure 37). Unlike other areas of the North Atlantic, the main species providing tridimensional structure to the seabed correspond to large gorgonian corals (Octocorallia, Alcyonacea), with many representatives of the suborders Holaxonia and Calcaxonia. Some examples would include the species *Viminella flagellum* and *Callogorgia verticillata* (Calcaxonia) but also *Dentomuricea* aff. *meteor* and *Acanthogorgia* sp. (Holaxonia). These four octocoral species thrive in hard surfaces of summits and upper slopes of most of the seamounts and ridges explored (Table 14), and are less frequently observed on the island slopes, especially those with high sedimentation rates. These corals can form very dense coral gardens, which are home to a wide variety of associated species, including mobile fauna such as fish and crustaceans (Figure 37a,b). The dominance in terms of abundance of one species over the others within this community is still a matter of study, and all possible combinations have been reported so far in the Azores region. The most common situation is that where the whip coral *Viminella flagellum* and/or the primnoid *Callogorgia verticillata* become the dominant species. Dense patches of the other two corals are less-frequently reported. For instance, dense aggregations of *Dentomuricea* aff. *meteor* have only been recorded in 5 areas so far, with the largest and most structurally complex populations observed in Cavala and Mar da Prata seamounts.

Another octocoral-dominated community found on the upper slopes of several seamounts corresponds to that formed by the bubblegum coral *Paragorgia johnsoni,* generally accompanied by a high number of small soft corals (e.g. P*seudoanthomastus* cf. *agaricus*) and cup corals (e.g. *Leptopsammia formosa*). Very large colonies of this gorgonian species have been observed in several seamounts of the MAR, especially in Beta and the Western ridge of the Gigante Seamount Complex (Figure 36). Also very characteristic in the MAR is the association formed by the octocoral *Pleurocorallium johnsoni* and the yellow laminate sponge cf. *Poecillastra compressa,* especially on the upper slopes between 500 and 700 m depth. This community is generally found on clean hard surfaces that show some inclination, especially on basaltic rock, although it has also been reported developing on lava balloons. A bit further deep (600-800 m), some dense aggregations of the primnoids *Narella bellissima* and *Narella versluysi* can become very common, sometimes covering extensive areas. This is the case of Cavalo and Formigas seamounts (Figure 37d), where very dense patches, mostly dominated by *N. versluysi*, have been observed for hundreds of meters. The number of species associated with this community is large, and includes not only sessile but also mobile fauna. Other less-common octocoral dominated communities correspond to those characterized by the primnoids *Candidella imbricata* and *Paracalyptrophora josephinae*. The former tends to generate extremely dense patches over boulders, with high numbers of associated species, with a limited spatial coverage. The latter has only been observed forming dense aggregations in Voador seamount, with most colonies of a great size and showing little signs of fishing impacts. It was always accompanied by a hydrozoan species, most likely *Lytocarpia myriophyllum*.

The deepest areas explored (1000-1400 m), generally at the base of the seamounts, are also home to another highly diverse mixed coral community, which includes several species of Plexauridae corals, black corals and bamboo corals. The densities of each species within this community are very variable, but the densest aggregations recorded so far have been observed in a deep ridge east of Gigante and in the Formigas seamount (Figure 37e). Some of the common fauna commonly observed include the Antipatharians *Leipathes expansa*, the bamboo corals *Lepidisis* sp, *Keratoisis* sp. and *Acanella arbuscula* and the octocorals *Iridogorgia* cf. *pourtalesii*, *Chrysogorgia agassizii*, *Hemicorallium tricolor* and *Paramuricea* sp., among others. The inaccessibility of this community and the lack of samples until recently implies that there are still some gaps in the identification of some species, especially those belonging to the Plexauridae family. Further efforts will be made to better understand the full diversity of this complex community.

Besides the octocoral-dominated communities, other cnidarian species are also responsible for dense aggregations that form structurally complex communities. This is the case of the stylasterid *Errina dabneyi* (Figure 37f), which has been observed forming highly dense patches in areas around islands of the central group, namely Capelinhos (W of Faial island) and the small seamounts southeast of Pico island. The fauna associated to these stylasterid aggregations is similar to that found on seamount summits, although in lower densities, with the four main octocorals listed previously (*V. flagellum*, *C. verticillata*, *Acanthogorgia sp.* and *D. meteor*). Although scleractinian corals are not very conspicuous in the Azores, at least in terms of biomass, some species identified in the images can be considered characteristic of several benthic communities. This is mainly the case of the azooxanthellate scleractinian of the family Dendrophylliidae *Eguchipsammia* cf. *cornucopia*, which is known to form reefs in at least two areas in the central group (Condor and SE Pico) and in the João Gaspar underwater volcano in the eastern group (South of São Miguel island), besides the first record discovered in the Faial-Pico Channel (Tempera et al., 2015).

At least six different sponge-dominated communities have been identified in the Azores deep-sea so far. Most seamounts of the MAR host aggregations of lithistid sponges, where the giant sponge cf. *Characella pachastrelloides* is the most conspicuous due to its large sizes. This sponge is generally found with other large lithistid Porifera in large rocky outcrops or on the slopes of the seamounts, generally below 600 m depth. Some of these species include *Petrosia crassa*, *Leiodermatium pfeifferae*, *Neophrisospongia nolitangiere* and *Macandrewia azorica* (Figure 37g), among others. When the mother rock has a basaltic origin (darker coloration), the sponge fauna shifts to a slightly different species composition, with a dominance encrusting sponges for which identification to species level for many of them has not yet been possible. Within those areas, the most common large porifera are *Craniella longipilis* and cf. *Haliclona magna*, sometimes reaching impressive sizes. On the summit of some seamounts, dense patches of the glass sponge *Asconema* sp. have been observed, generally covering small areas. This Rossellidae sponge tends to appear as an accompanying species in other communities, and such aggregations seem to be rare and have only been reported in three seamounts so far: Beta, Sarda and Condor. Another hexactinellid sponge that can also form dense aggregations in the Azores deep sea is the tubular *Pheronema carpenteri* (Figure 37h). This species is commonly observed on soft or mixed substrates in deeper areas, usually on seamounts or slopes characterized by high rates of sediment deposition. Some of the densest aggregations have been observed on Condor seamount and on the slopes of Pico island. The remaining sponge communities found in the features evaluated are characterized by small pedunculate sponges (*Hyalonema* sp. and *Stylocordyla pellita*; Figure 37i), which develop over soft sediments in some of the deepest areas (1000 m). Their distribution is so far restricted to Formigas and Sarda seamounts, which could change when the base of other seamounts is explored.

Finally, besides the coral- and sponge-dominated communities, fauna from other phyla have also been identified as characteristic species in other benthic communities, including some aggregations of echinoderms such as sea urchins or sea stars. Especially relevant, is the case of the 'living fossil' community (sensu Wisshak et al., 2009) characterized by the deep-sea oyster cf. *Neopycnodonte zibrowii* and the crinoid cf. *Cyathidium foresti* on vertical walls of seamounts and island slopes (Figure 37j). Another important aggregation found in many areas of the Azores is that formed by the xenophyophore cf. *Syringammina fragilissima*, wich develops in soft bottoms of mud/sand at the base of the seamounts. It is usually found past 1000 m depth, although it has been observed up to 700 m depth on the slopes of Pico island. The densities of this foraminiferan are generally low, but it extends for large areas when present.

As it can be observed in Figure 36, the spatial coverage of the video recordings evaluated for this report is relatively large, so the characterization of deep-sea benthic communities can be considered representative of the depth range explored. However, further efforts are still required to understand how benthic diversity is organized spatially below 800 m depth. The number of seamounts for which video data is available past those depths is still limited, with only a few representatives so far. Furthermore, some knowledge gaps still exist around the islands that make up the western group, for which no information is currently available, as well as those seamounts and ridges located on the MAR north of Oscar seamount (39º 35' N).

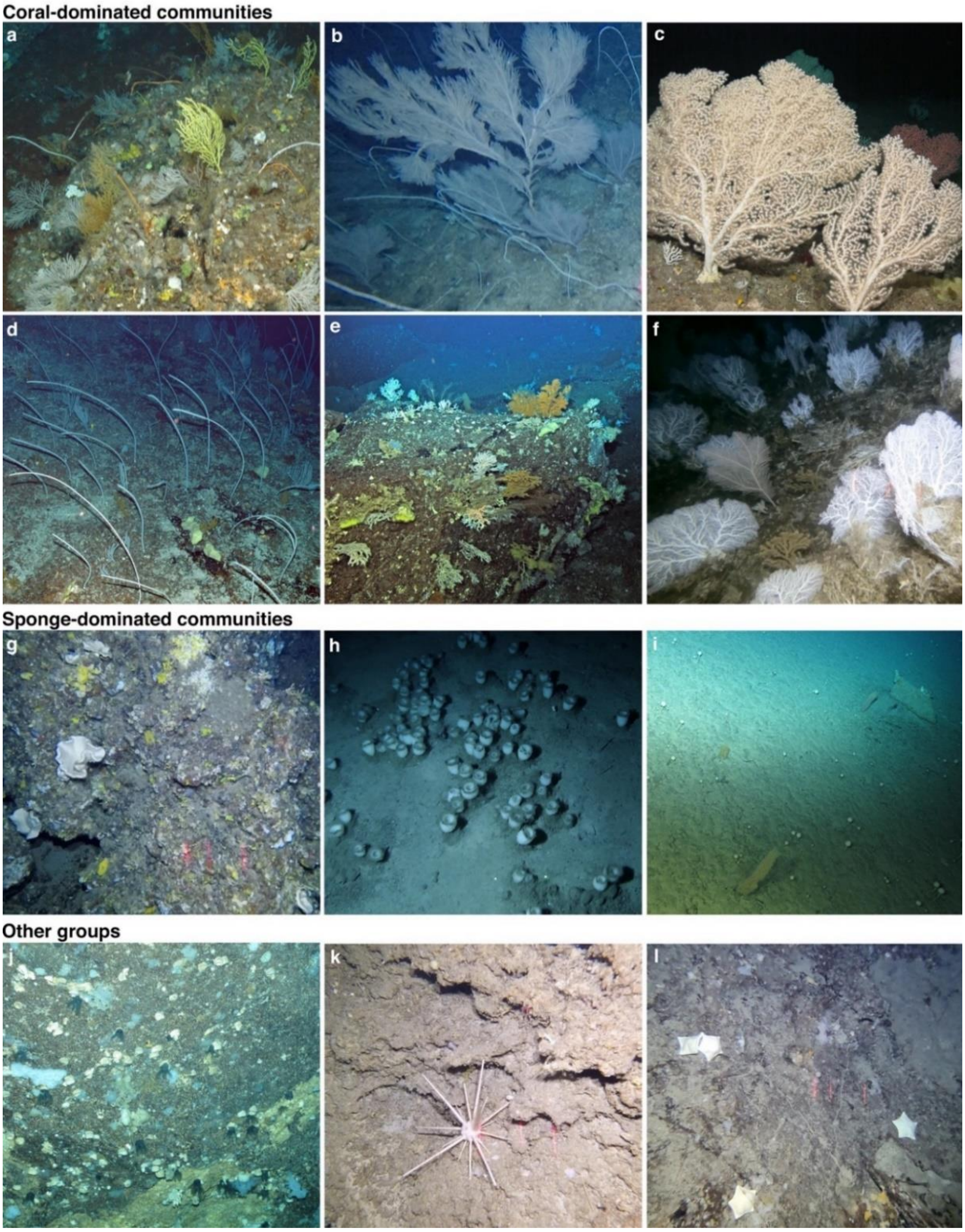


Figure 37. Some examples of benthic communities identified in the Azores deep sea. (a) Very diverse patch on a large boulder with the octocorals *Viminella flagellum*, *Acanthogorgia* cf. *hirsuta*, *Dentomuricea* aff. *meteor* in Gigante seamount. (b) Large colonies of *Callogorgia verticillata* and *Viminella flagellum* observed in Picoto seamount. (c) A dense aggregation of the stylasterid *Errina dabneyi* in Capelinhos. (d) Large *Paragorgia johnsoni* colonies found on the slopes of the western ridge, in the Gigante Seamount Complex. (e) Dense aggregation of the Primnoid *Narella versluysi* with a few other corals and glass sponges in Formigas seamount. (f) Aspect of a large rocky outcrops colonized by cold-water corals, including several species of scleractinians, octocorals, black corals and bamboo corals below 1000 m depth in Formigas seamount. (g) Some of the various species of Porifera observed on large rocky outcrops and vertical walls in Voador seamount. (h) Aggregation of the hexactinellid *Pheronema carpenteri* in Condor seamount. (i) Dense aggregation of the pedunculate sponge *Stylocordyla pellita*. (j) Ancient community found in vertical walls with cf. *Cyathidium foresti*. (k) Bare outcropping rocks with the long-spine sea urchin cf. *Cidaris cidaris* in Ferradura seamount. (l). Some sea stars of the family Goniasteridae in Oscar seamount. The complete list of benthic communities is provided in Table 14. a,c © ROV Luso/EMEPC / 2018 Oceano Azul Expedition; b,f,g,k,l © Drift cam, IMAR/Okeanos UAç; d,e,j ©Medwaves, ATLAS project; h © Hopper tow-cam, NIOZ.

Table 14. Summary of the main benthic communities that have been identified so far in each of the features (ridges -Rg-, seamounts -Smt- or slopes -Sl-) visually investigated in the Azores EEZ. The species names given in each category represent the most conspicuous/abundant organism, and does not imply the lack of other associated/structural fauna.

	Mid-Atlantic Ridge																Central									Eastern		
Benthic communities	Oscar	Gigante	127	Western Rg.	Rg. E. Gigante	A6	Ferradura	Cavala	Beta	Picoto	Alfa	Voador	Monte Alto	A3	Sarda	Cavalo	Condor	Capelinhos	S. Mateus smt	Sl. Pico	Sl. S. Jorge	SE of Pico	S. Jorge de	Sl. Terceira	D. João Castro	Alcatraz	Mar da Plata	Formigas
Coral-dominated communities																												
Mixed coral gardens with the octocorals *V. flagellum*, *C. verticillata*, *A. hirsuta*, *D. meteor*																												
Monospecific or dominated by *Viminella flagellum*	•	•	•	•		•	•	•		•	•	•	•	•	•		•						•	•	•	•		
Monospecific or dominated by *Callogorgia verticillata*	•						•			•		•	•		•		•	•				•	•		•			
Monospecific or dominated by *Acanthogorgia* cf. *hirsuta*	•	•		•												•	•	•				•						
Monospecific or dominated by *Dentomuricea* aff. *meteor*		•						•									•					•					•	
Coral gardens with *Paragorgia johnsoni* & *Pseudoanthomastus* cf.*agaricus*		•		•			•	•	•		•				•									•				
Coral gardens with *Pleurocorallium johnsoni* & cf. *Poecillastra compressa*	•	•	•	•		•		•		•	•				•													
Coral gardens with *Narella versluysi* & *Narella bellissima*	•	•				•	•		•						•	•			•				•					•
Coral gardens with *Candidella imbricata*		•										•			•		•											•
Coral gardens with *Paracalyptrophora josephinae* & cf. *Lytocarpia myriophyllum*												•																
Coral gardens with *Errina dabneyi*																		•				•						
Fields of *Acanella arbuscula*																							•					•
Fields of large hydrozoans												•					•	•										
Fields of soft corals																		•										
Fields of *Leptopsammia formosa*	•																			•				•				
Fields of *Crypthellia vascomarquesi*																							•					•
Reefs of *Eguchipsammia* cf. *cornucopia*																	•					•						
Mixed coral gardens with several Antipatharians, bamboo corals and Plexauridae					•																							•
Vertical walls; *Leiopathes expansa*, *Lophelia pertusa*, *Dendrophyllia cornigera* & *Farrea occa*																			•	•								
Aggregations of *Flabellum* spp.	•		•	•		•	•						•				•											
Deposits of coral rubble	•	•		•		•	•	•	•	•	•	•		•	•			•	•	•		•	•					•
Sponge-dominated communities																												
Agg. of lithistid Porifera *C. pachastrelloides, P. crassa, Leiodermatium* & *N. nolitangiere*		•	•	•				•	•			•	•	•	•		•		•	•	•	•		•	•	•	•	
Aggregations of encrusting and other large lithistid Porifera on basaltic rock	•	•	•	•		•	•	•		•	•	•	•	•		•			•									
Fields of *Pheronema carpenteri*		•			•	•									•		•		•	•			•	•				•
Fields of *Asconema* sp.									•						•		•											
Fields of *Stylacordilla pellita*																												•
Fields of *Hyalonema* sp.															•													
Other groups																												
Aggregations of *Cidaris cidaris*		•	•				•	•																				•
Fields of cf. *Syringammina fragilissima*															•		•		•	•			•	•				
Vertical walls with cf. *Neopycnodonte zibrowii* & cf. *Cyathidium foresti*																			•	•	•							•
Aggregations of Goniasteridae sp.	•																											

The underwater features described above were assessed against each of the five FAO criteria for defining what constitutes a VME (see Section 5.1.5) using expert judgement. Thirteen out of the 28 features visually evaluated were identified as priority areas for conservation (Table 15). These features were generally characterized by a great diversity of species and biological communities, with unique characteristics in terms of the composition of endemic, rare or threatened species (FAO criteria 1), and/or communities composed of tall, and arborescent species that provide complex habitat for other species (FAO criteria 5). The fragility of the habitat-forming species (FAO criteria 3) was based on evidence of vulnerability to physical contact, such as accidental capture during longline fishing (based on Sampaio et al., 2012; COLETA database), and the capacity of species for retraction, retention or re-growth or natural protection in some way (e.g. vertical walls or overhangs not accessible by fishing or located below maximum longline fishing depths). In most instances, large organisms with complex 3D morphologies, e.g. octocorals such as *Callogorgia verticillata*, *Paracalypthrophora josephinae*, *Paragorgia jonhsoni* and black coral *Leiopathes* spp., are also more susceptible to longline fishing, with their removal significantly reducing habitat complexity of the underwater features where they occur.

In general, there was limited information to assess the life history and functional significance of the species/communities (FAO criteria 2 and 4 respectively) due to major knowledge gaps on species reproductive cycles, growth rates, reproductive output, larvae biology and dispersal, recruitment and their role in the functioning of the ecosystems such as nursery areas for other species, nutrient regeneration, and carbon remineralization and sequestration. When available, information on life-history traits for closely related species or same taxa was used as a proxy to score for that criteria, based on the assumption that these traits are phylogenetically conserved (Kraft et al., 2007). As for the functional significance of the habitat, there is information regarding fish and sharks' aggregations in or close to coral gardens, for example the deep-water shark *Dalathias licha* and the fish *Hoplostethus mediterraneus* in Gigante seamount. However, it is difficult to infer a direct link between habitat-forming species such as corals or sponges and their role as nursery grounds, especially based on observed adult fish and shark species. Because of limited knowledge, in most cases it was assumed that those features that presented the highest diversity of species and communities had a potentially higher functional significance. This is based on studies that show a direct relationship between biodiversity and ecosystem functioning for deep-sea ecosystems (Snelgrove et al., 2014; Zeppilli et al., 2016) and how habitat heterogeneity increases the number of niches for associated species, ecological interactions, and food web complexity (Buhl-Mortensen et al., 2010; Zeppilli et al., 2016). Though, as new scientific knowledge is gathered in the future, a better assessment of these criteria will be possible.

The MAR region included the greatest number of underwater features that fit the FAO criteria for VME (Table 15). A high number of distinctive communities was found for most of these features, composed of tall arborescent colonies of long-lived, slow-growing species with low reproductive output (e.g. *Paragorgia johnsoni*, *Pleurocorallium johnsoni*, *Callogorgia verticillata*, *Paracalypthrophora josephinae*, *Keratoisis*, *Lepidisis*, *Leiopathes* sp.: Andrews et al., 2009; Sherwood & Edinger, 2009; Carreiro-Silva et al., 2013; Perrin et al., 2015), and highly susceptible to the impact of fishing (Sampaio et al., 2012). Notable in this region was also the newly discovered hydrothermal vent field Luso, which differs considerably from other known hydrothermal fields along the MAR (see Section 2.1.3). In the case of the Ridge east of Gigante, important communities were recorded in deep areas naturally protected from longline fishing. However, the presence of millennia-old black corals and century-old bamboo corals not found in shallower areas, justifies their inclusion as priority areas for conservation. In addition, in these deeper and less explored areas, several unidentified corals of the family Plexauridae were recorded and may be new to science.

In the Central group, Condor seamount was distinguished by a high number of dissimilar coral and sponge communities over a wide bathymetric range (Table 14), further emphasizing the importance of this seamount for scientific research (Morato et al., 2010). Dom João de Castro seamount was notable for the very dense *Callogorgia verticillata* gardens in deep areas (300-400 m) and hydrothermal vents at shallow depths (20 m depth). Underwater features of SE of Pico and Capelinhos, were also particularly diverse and unique, with dense communities of the endemic and fragile stylasterid species *Errina dabneyi*, not commonly found in other areas. The SE Pico was also distinguished by an extensive reef formed by the scleractinian *Eguchipsammia* cf. *cornucopia*, a species not known to form reefs elsewhere in the Atlantic and representing a potential relict species from the geological past (Tempera et al., 2015). In Capelinhos, dense coral gardens of the black coral *Antipathella subpinnata* were associated with millennia-old black coral *Leiopathes* sp. together with very dense patches of the stylasterid *Errina dabneyi*. Although not recorded in our surveys, well-developed reefs of *Lophelia pertusa* are also reported for Capelinhos (Rebikoff-Niggeler Foundation, unpub. data), further highlighting the high diversity of communities of this area. In the Eastern group, Formigas was particularly diverse, with well-preserved communities showing little impact from fishing and the presence of several large colonies of *Leiopathes* sp.

Based on this assessment, 12 large areas where identified that fit the FAO criteria defining what constitutes a Vulnerable Marine Ecosystem (FAO, 2009). These areas consist of 3 portions of the MAR (Western ridge, Ridge east of Gigante, Cavalo), eight seamounts (Oscar, Gigante, Cavala, Beta, Voador, Condor, Don João de Castro, and Formigas), and an area with several small mounds south-east of Pico island. The seafloor west of Capelinhos volcano, in Faial island, also fitted the FAO criteria and considered a VME but was not included in this prioritization approach since the surveyed areas are located outside the spatial planning area (i.e. within 6nm from shore). A contour of these 12 areas was computed using the best available bathymetry data. The PUs covered by more than 5% by these VME polygons were kept as important areas.

Table 15. Assessment of underwater features against five criteria for defining what constitutes a Vulnerable Marine Ecosystem (FAO, 2009). Low fit to a criterion is coloured in light blue, medium in dark blue, high in pink, and very high in red. Features identified as Important areas are highlighted in ***bold*** and grey.

Area	Underwater Feature	*Unique*	*Functional*	*Fragility*	*Life history*	*Structural*	General description
MAR	***Oscar***						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of benthic communities. Dense coral gardens dominated by octocorals, particularly *Callogorgia verticillata* with large colonies (~1.5 m height) not seen in many other areas. *C. verticillata* has low growth rates and low reproductive output (Carreiro-Silva, unpub. data) and is highly susceptible to fishing based on fisheries bycatch data (Sampaio et al., 2012).
	Gigante						FAO listed VME hydrothermal vent, presence of the potentially endemic species *Dentomuricea* aff. *meteor*. High diversity of species and communities. Hydrothermal vent Luso. Dense coral gardens dominated by octocorals, particularly *Paragogia johnsoni* with large colonies (~1.5 m height) and the potentially endemic *D. meteor*. *P. johnsoni* highly susceptible to fishing based on damaged colonies observed in video surveys. *Paragorgia* species have high longevity (~ 100 years) and slow growth rates (Sherwood & Edinger, 2009).
	127						Low abundance of habitat-building corals and sponges; hard substrates dominated by sponges and widespread octocoral *Viminella flagellum.*
	Western ridge						Species with mixed amphi-Atlantic and Atlanto-Mediterranean distribution. Populations of CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*. Dense *Paragorgia johnsoni* gardens with some of the largest colonies recorded so far showing little impact from fishing.
	Ridge east of Gigante						CITES listed black coral species *Leiopathes*. Diverse coral communities composed by large structuring species such as bamboo corals *(Lepidisis* and *Keratoisis)* and the black coral *Leiopathes* spp. These species are characterized by low growth rates, high longevities (centuries to millennia for bamboo corals and black corals respectively, Andrews et al., 2009; Carreiro-Silva et al., 2013). Presence of several corals of the family Plexauridae, not seen elsewhere and that may be new to Science. Communities naturally protected from fishing impacts because of great depths (below 1000 m).
	A6						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of coral and sponge species. Communities with a dominance of sponges species.
	Ferradura						CITES listed black coral species *Leiopathes*. Dense coral gardens dominated by octocorals, with some evidence of fishing impact.
	Cavala						Presence of the potentially endemic species *Dentomuricea* aff. *meteor*. High diversity of species and communities. Dense coral gardens dominated by *D. meteor,* one of the densest recorded in the Azores so far. Presence of large *Paragorgia johnsoni, Pleurocorallium johnsoni* and *Paracalypthrophora josephinae*. Species highly susceptible to fishing based on bycatch data (Sampaio et al., 2012) or evidence of broken colonies in video surveys. Structural species characterized by slow growth and low reproductive output (Sherwood and Edinger, 2009; Perrin et al., 2015, Carreiro-Silva, unpub. data).

Area	Underwater Feature	Unique	Functional	Fragility	Life history	Structural	General description
	Beta						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Dense and diverse coral gardens dominated by large octocorals and sponge aggregations. Dense *Paragorgia johnsoni* gardens with some very large colonies. Communities generally well preserved, showing little impact from fishing.
	Picoto						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of benthic communities. Coral gardens dominated by the octocorals *Viminella flagellum* and *Callogorgia verticillata,* with some very tall colonies that showed little impact from fishing.
	Alfa						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of benthic communities and overall low densities of corals and sponges, generally of small sized specimens. Evidence of fishing impacts.
	Voador						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of species and communities. Densest coral gardens of the octocoral *Paracalypthrophora josephinae* observed in the Azores so far, with the presence of tall colonies. Species highly susceptible to fishing based on bycatch data (Sampaio et al., 2012); and low growth rates and reproductive output (Carreiro-Silva, unpub. data). Dense aggregation of *Candidella imbricata* at shallow depths.
	Monte Alto						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low number of benthic communities, with low densities overall.
	A3						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of coral and sponge species and communities. Mostly species of small size.
	Sarda						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High number of benthic communities observed. Diverse coral and sponge assemblages, although some are very localized in space. Presence of large colonies of *Paragorgia johnsoni* and *Callogorgia verticillata*, which are slow-growing, long-lived species susceptible to fishing (Sampaio et al., 2012).
	Cavalo						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of species and communities. Dense coral gardens dominated by octocorals *Narella versluysi* and *N. bellissima,* largest aggregations recorded in the Azores so far. Presence of large colonies of the octocorals *Paragorgia johnsoni* and *Callogorgia verticillata*, which are slow-growing, long-lived species susceptible to fishing (Sampaio et al., 2012).
Central	***Condor***						Populations of the potentially endemic species *Dentomuricea* aff. *meteor* and CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*. High diversity of species and communities. Mixed coral gardens composed of several octocoral species and sponge aggregations. Slow growing, long-lived species susceptible to fishing based on bycatch data (Sampaio et al., 2012). Reefs of *E. cornucopia*, a species not known to form reefs elsewhere in the Atlantic and to represent a potential relict species from geological past (Tempera et al., 2015). Seamount important for scientific research (Morato et al., 2010).
	Capelinhos						Populations of the potentially endemic octocoral species *Dentomuricea* aff. *meteor* and stylasterid *Errina dabneyi* and CITES listed black corals *Antipathella subpinnata*, *Leiopathes* sp. and stylasterid *Errina dabneyi*. High diversity of species and communities. Dense coral gardens formed by octocorals, black corals and stylasterids. Dense mesophotic coral gardens dominated by the soft coral cf. *Alcyonium* sp. Presence of large

Area	Underwater Feature	Unique	Functional	Fragility	Life history	Structural	General description
							colonies of millennia-old *Leiopathes* sp. Evidence of shark aggregations. Little impact from fishing due to absence of longline fishing. Area important for geology and scientific research.
	Baixo São Mateus						Presence of "fossil community" composed of long-lived oysters and crinoids (cf. *Neopycnodonte zibrowii* and cf. *Cyathidium foresti*) found only in the Azores. Low diversity of species and communities in vertical walls, naturally protected from fishing. Presence of large sponges cf. *Characella pachastrelloides*. Presence of numerous fishing lines indicating high pressure from fishing.
	Slopes of Pico						Presence of "fossil community" composed of long-lived oysters and cirripeds (cf. *Neopycnodonte zibrowii* and cf. *Cyathidium foresti*) found only in the Azores. High diversity of corals and sponges but sparsely occurring on large boulders and mostly of small sizes. Communities in vertical walls naturally protected from fishing.
	SE of Pico						Presence of the potentially endemic species *Dentomuricea* aff. *meteor* and CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*, black coral *Antipathella subpinnata* and stylasterid *Errina dabneyi*. High diversity of species and communities. Dense coral gardens dominated by octocorals and sponges. Species with low growth and reproductive output vulnerable to fishing (Sampaio et al., 2012). Reefs of *E. cornucopia,* a species not known to form reefs elsewhere in the Atlantic and representing a potential relict species from geological past (Tempera et al., 2015).
	Slopes of São Jorge						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of corals and sponges and mostly of small size. Communities in vertical walls naturally protected from fishing.
	São Jorge de Fora						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Although the number of communities identified is high, they are very localized in space and species showing low densities overall. Presence of *Callogorgia verticillata*, slow growing, long-lived species susceptible to fishing (Sampaio et al., 2012).
	Slopes of Terceira						Species with amphi-Atlantic or Atlanto-Mediterranean distribution Low diversity of species and communities, although the presence of a few large colonies of *Paragorgia johnsoni* and *Pleurocorallium johnsoni*, showing impacts from fishing.
	Dom João de Castro						FAO listed VME hydrothermal vent, species with amphi-Atlantic or Atlanto-Mediterranean distribution. Dense coral gardens dominated by octocorals, particularly *Callogorgia verticillata,* with the presence of many large colonies. Few signs of fishing impacts.
Eastern	Alcatraz						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of species and communities. Presence of large sponges *Characella pachastrelloides*. Evidence of fishing impacts.
	Mar da Prata						Presence of the potentially endemic species *Dentomuricea* aff. *meteor*. Dense coral gardens dominated by octocorals and diverse sponge aggregations but covering a small area. Evidence of fishing impacts.
	Formigas						Presence of CITES listed black coral *Leiopathes* sp. High diversity of species and communities. Dense coral gardens dominated by octocorals and black corals, and diverse sponge aggregations. Millennia-old black coral *Leiopathes*. Communities generally well preserved, showing little impacts from fishing.

5.1.7 *Important areas: other known important areas*

Essential fish habitats

Several international fisheries regulations recognised that the sustainable exploitation of marine fisheries resources must include greater protection for fish habitats critical for their survival, growth, and reproduction (Nimick & Harris, 2017; Vaz & Pape, 2019). For example, the FAO Code of Conduct for Responsible Fisheries from 1995, the U.S. Fishery Conservation and Management Act from 1996, and the European Common Fisheries Policy (CFP; e.g. EU Reg No 1343/2011) have all considered the need for increased protection of essential fish habitats (EFH). In the context of the ecosystem approach to fisheries management, the EU CFP (Article 8) requested the effective protection of Fish Stock Recovery Areas (FSRAs), such as EFH, since they can contribute to rebuilding exploited fish stocks. EFHs can be broadly defined as those waters and substrates essential to the ecological and biological requirements for critical life-history stages of exploited fish and, therefore, necessary to fish for spawning, breeding, feeding, growth to maturity, or for migrations (Schmitten, 1999; Rosenberg et al., 2000; STECF, 2006). Guidelines assume the scientific information necessary to make informed EFH designations is available, but this not often the case because the habitat requirements for most marine species are poorly understood (Nimick & Harris, 2017). Nevertheless, and acknowledging all knowledge gaps and uncertainties, several attempts to identify EFHs have been conducted worldwide (Lindeman et al., 2000; Bergmann et al., 2004; Cook & Auster, 2005; Laman et al., 2018; Afonso et al., 2020) and some fisheries restricted areas to protect EFHs have been already agreed (EU Reg 1343/2011).

The considerations of EFHs in the Azores was considered relevant to address the management objectives related to the protection of essential fish habitats, protection of vulnerable, endangered, or critically endangered species, and rebuild fish stocks. Information on essential fish habitats for commercially important deep-sea benthic species in the Azores is very scarce. However, some offshore spawning areas that concentrate an important part of reproductive adults of some exploited species have been suggested as examples of EFH. The Sedlo seamount complex was considered an EFH because of the observations of massive reproductive aggregations of orange roughy (*Hoplostethus atlanticus*), splendid alfonsino (*Beryx splendens*) and cardinalfish (*Epigonus telescopus*) (Santos et al., 2010; Menezes et al., 2012). Additionally, the Hard Rock Cafe seamount was also considered an EFH because of the large spawning aggregations for orange roughy observed during trawl bottom fishing experiments (Melo and Menezes, 2002a,b). Although we recognize that there is an insufficient understanding of what is an essential habitat in the Azores, these two areas (Sedlo and Hard Rock Café seamounts) were included in the prioritization approach (Figure 39). A contour of the 900m depth was used to delimit the seamounts peaks. The PUs covered by more than 5% by these EFH polygons were kept as important areas.

Shallow and very deep seamounts

Because of the perceived rich biodiversity and vulnerability of some seamount communities to human activities, Watling & Auster (2017) suggested that seamounts should be managed as VMEs. Although not all seamounts are the same (Taranto et al., 2012; Kvile et al., 2014), shallow-water seamounts (with summits shallower of approximately 250m depth) may be considered important areas because of the communities they host, their ecological role for demersal fish, and their resilience potential towards climate change (Rogers et al., 2007; Tittensor et al., 2010; Morato et al., 2013; Kvile et al., 2014). These seamounts have often been nominated as biodiversity hotspots not only for the benthic fauna (Kvile et al., 2014) but also for the large megafauna that visits these features (Morato et al., 2010; 2016; Afonso et al., 2020). The biology, ecology, and function of deep seamounts located in abyssal plains are much less understood. However, recent studies have shown abyssal seamounts are hidden sources of increased habitat heterogeneity, with distinct benthic megafaunal diversity, and that may act as valuable biodiversity reservoirs in the large abyssal plain (Durden et al., 2015; Lapointe et al., 2020).

The identification and protection of very shallow and very deep seamounts was considered relevant to address management objectives related to protecting hotspots of biodiversity, maintain biological diversity, and rebuild fish stocks in the "data-rich" area. Information on the location of shallow water seamounts is adequate since great efforts to map the shallower portion of the Azores EEZ have been made in recent years by the Portuguese Hydrographic Institute (Appendix 1.1.2). However, most of the abyssal plain in the Azores is still to be mapped with multibeam and therefore many very deep topographic features are still to be revealed. Eleven shallow water seamounts located in the "data-rich" area were included in the prioritization approach (Figure 39): Açor (summit at 160m depth), Condor (190m depth), Don João de Castro (20m depth), Formigas (0m depth), Gigante (160m depth), Gigante 127 (160m depth), Grande Norte (120m depth), Mar da Prata Norte (170m depth) and Mar da Prata Sul (260m depth), Princesa Alice (40m depth), and Voador (230m depth). A radius of 3km from the shallowest peak was used to delimit these seamounts and all PU intersecting these buffers were classified as important areas. Additionally, two deep seamounts (both probably named São Mateus de fora) roughly deeper than 1400m, were identified in the "data-rich" area (GMU High Relief Peak deeper than 1400m). This area was considered as important in the data-rich area because of its uniqueness and potential for hosting rich benthic biological communities. A contour of the 1800m depth was used to delimit a buffer around the two peaks of this seamount. PUs covered by more than 10% by this deep seamount were kept as important areas.

Near-natural areas

Similar to EFH, several international regulations recognised the importance of greater protection for areas with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation (e.g. CBD COP decision IX/20 Annex I). Areas with near-natural structures, processes and functions are important reference sites that can help setting conservation goals and objectives, guiding trajectories of recovery of impacted sites, and inform adaptive management. Near natural areas may also qualify as Fish Stock Recovery Areas and contribute to rebuilding exploited fish stocks. Here, we defined near-natural areas as those geomorphological features that have not been impacted by fishing but show high potential for hosting of vulnerable, endangered, or critically endangered species or habitats. Hence, the protection of near-natural areas may contribute to the management goals and objectives of protection of vulnerable species or habitats, maintaining the biological diversity of deep-sea ecosystems, and may also contribute to rebuilding fish stocks. Obviously, it will also contribute to ensuring the protection of potential near-natural areas.

Potential near-natural seabed areas in the Azores were defined as those areas within fishable depths (i.e. shallower than 1200m) that may not have been exploited by deep-sea bottom fishing. The analyses of VMS data for the period 2002 to 2018 indicated that apparently all geomorphologic features shallower than 1000m depth have been fished to some extent (Appendix 1.5.3). However, 2019 multibeam bathymetry surveys conducted by the Portuguese Hydrographic Institute (Instituto Hidrográfico, IH) south of the Flores islands revealed that the small Diogo de Teive seamount is much shallower (585m depth) than previously thought (960m depth). After a careful look at the VMS data, no indication of fisheries exploitation could be identified, which may point to Diogo de Teive being a near-natural area. However, a careful examination of the deep-sea benthic communities inhabiting this seamount could give more insights into the levels of potential fishing impacts. Based on this information, Diogo de Teive seamount was included in the prioritization approach as the only near-natural area in the Azores EEZ (Figure 39). This important area was composed of only one PU capturing the 850m depth contour.

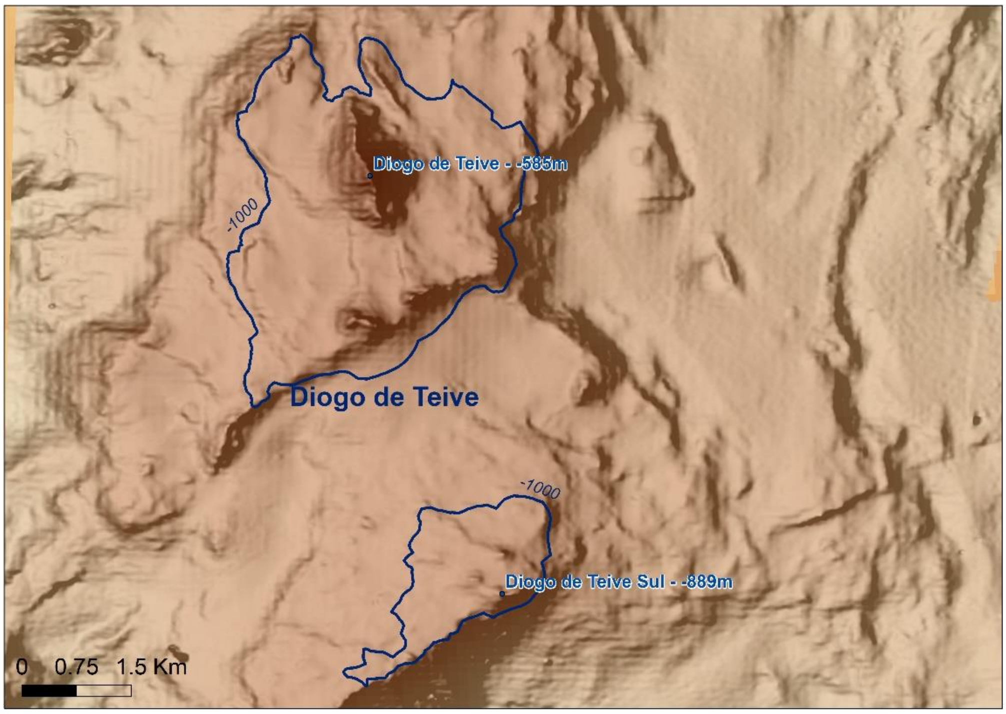


Figure 38. Multibeam bathymetry surveys conducted by the Portuguese Hydrographic Institute (Instituto Hidrográfico, IH) south of the Flores islands revealed the small Diogo de Teive seamount is shallower than previously thought.

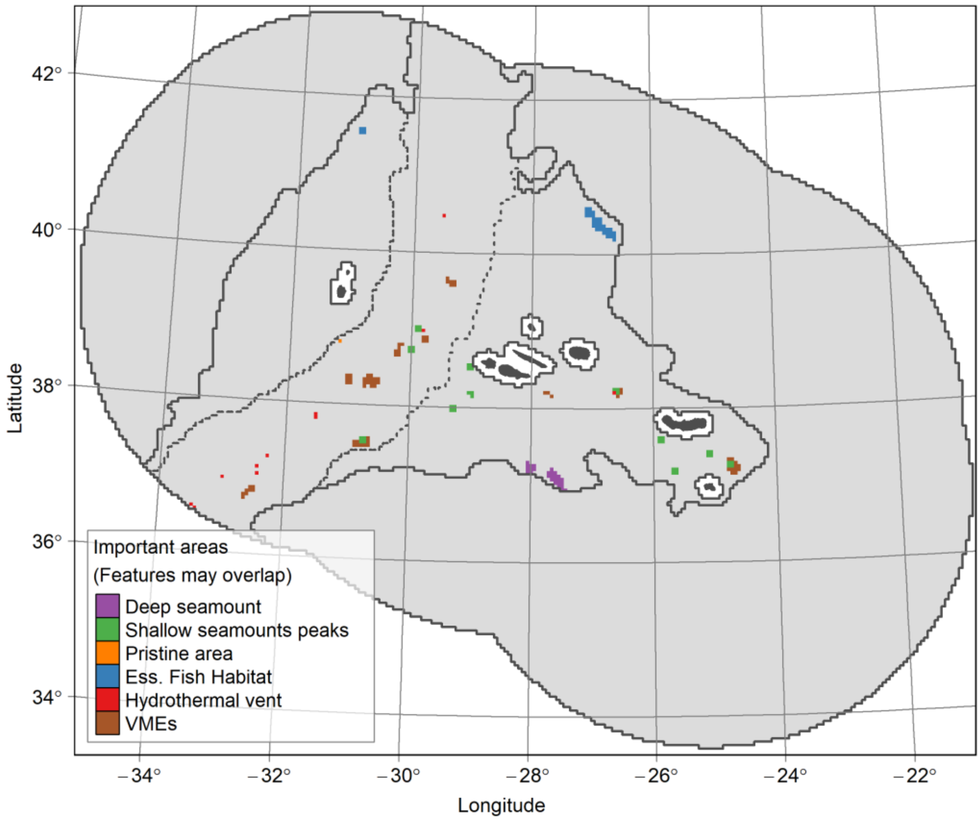


Figure 39. Map displaying the location of the PUs that contain important areas and have been included in the prioritization approach. Features may overlap.

Several important areas were considered in the "data-rich" area, adding up to about 1.48% of the total "data-rich" planning area (Figure 39, Table 16). These areas were always included in prioritization solutions using a 100% conservation target (equivalent to a "lock-in" constraint). In general, the important areas a large portion of the conservation features considered useful to address the management and conservation goals and objectives, namely the commercially important deep-sea fish, the habitat-structuring CWC, the CWC records, inferred VMEs, shallow depth classes and shallow GMUs (Table 17). Based on the best currently available knowledge, the main or larger important areas were included in the conservation planning approach, but we acknowledge that others may exist, that have not yet been discovered, that are rather small, very localized, or less known. This is the case, for instance, of ancient, old and large *Leiopathes* sp. coral colonies, that although partly represented in the VME layer, have unknown precise locations, abundance and spatial extent. More scientific research is necessary to better understand their distribution and structural and functional role in the ecosystem.

Table 16. Summary of Important areas considered in the systematic conservation planning approach. *Less than the sum because some PUs contains several important areas.

Important areas	N of areas	Method for extracting in PUs	N of PUs	% of "data-rich" area
Known VMEs	12	PUs covered by >5%	88	0.69
Hydrothermal vents	10	Presence	11	0.09
Essential Fish Habitats	2	PUs covered by >5%	35	0.27
Shallow-water seamounts peaks	11	Presence of 3km buffer	43	0.34
Deep seamounts in the data-rich area	2	PUs covered by >10%	28	0.22
Near natural areas	1	Presence of near-natural area	1	0.01
Total	30*		189*	1.48*

Table 17. Proportion of the conservation features (Section 5.1) that are included in the important areas identified in the present study.

Feature	Feature description	% inside important areas
Commercially important deep-sea fish; HSM	*B. splendens*	11.93
	P. kuhlii	29.63
	H. dactylopterus	11.50
	P. americanus	12.56
	P. bogaraveo	19.86
	B. decadactylus	10.48
Vulnerable deep-sea sharks and rays; HSM	*C. squamosus*	7.66
	C. coelolepis	1.05
	C. owstonii	1.02
	C. crepidater	3.61
	D. licha	11.07
	D. calcea	4.97
	D. profundorum	11.38
	D. batis	8.34
	E. pusillus	13.33
	E. spinax	7.79
	L. fullonica	5.74
	S. laticaudus	13.50
Habitat-structuring CWC; HSM	*C. verticillata*	23.55
	P. josephinae	25.95
	P. johnsoni	16.68
	Coral garden	34.46

Feature	Feature description	% inside important areas
CWC records	*E. dabneyi*	27.66
	Leiopathes spp.	36.11
	L. pertusa	42.86
	M. oculata	30.77
Inferred VMEs	VME index	23.6
Important areas	Important areas	100.0
Depth class	0 to 600m	16.76
	600 to 800m	10.64
	800 to 1200m	8.02
	1200 to 2500m	0.65
	Deeper than 2500m	0.02
GMUs	Island shelf	23.70
	Island shelf unit	3.31
	High relief peak	21.02
	High relief unit	7.26
	Low relief peak	1.28
	Low relief unit	0.18
	Depression	0.18
	Hills	0.51
	Flat area	

5.2 Constraints and penalties

5.2.1 Constraint on existing marine reserves

Several MPAs have been designated in the Azores over the last three decades (see Section 2.3.2) with various objectives and goals, that can be slightly different from those developed herein. Previous MPAs and fisheries closures designs in the Azores have not followed systematic approaches but instead resulted from the identification of important areas for conservation and one area important for scientific research (Condor seamount). This last example involved difficult negotiations and compromises between various stakeholders. Existing marine reserves (i.e. no-take MPAs) in the Azores are thought to have high conservation value (Abecassis et al., 2015) and they form a network that is already legally established. However, some studies pointed to a reduced value of the MPAs that were not designed based on a systematic approach, and that including them in the prioritization approaches may produce under-performing results in comparison to a network started from scratch (Evans et al., 2015; Moore et al., 2016). Following this recommendation, the existing network of no-take MPAs in the Azores was not included in the spatial prioritization approach to avoid constraining the selection of priority areas designed to address specific management and conservation goals and objectives. However, the existing network of MPAs were considered when simplifying and summarizing the SCP outputs (Section 0).

Spatial information on the existing MPAs in the spatial planning area was obtained from the Regional Government of Azores, from current regulations and complemented with data from the World Database on Protected Areas (UNEP-WCMC and IUCN, 2019). Among them, seven MPAs ensure protection for the deep-sea ecosystem (e.g. bottom fisheries closures) and were considered as deep-sea marine reserves (Figure 40): the Marine Natural Reserves of Don João de Castro, Formigas and Sedlo seamount, Menez Gwen and Lucky Strike hydrothermal vents, and the fisheries closed areas of the Condor seamount and the Luso hydrothermal vent. The other 6 MPAs have a lower level of protection that cannot ensure the full protection of the seabed ecosystems they host, and thus were not considered in the gap analysis. The PUs that intersected at least 30% of marine reserves polygons (n=234) covered about 0.6 % of the whole planning area; 1.5% of the "data-rich" area and 0.1% of the "data-poor abyssal" area. We used this existing network of marine reserves to have an estimate of the conservation features (Section 5.1) that are currently protected (Table 18).

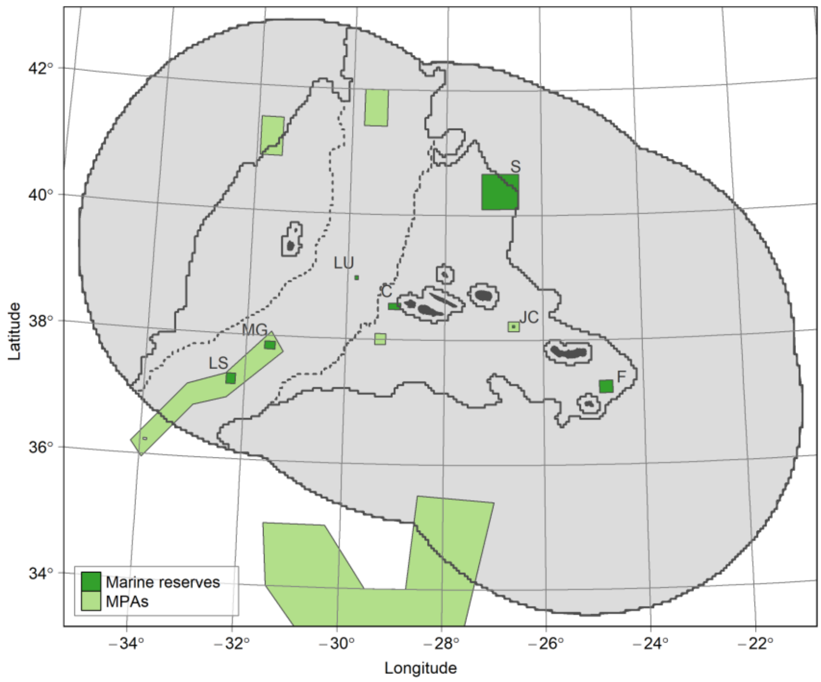


Figure 40. Existing marine protected areas in the spatial planning area. Marine reserves and fishing closures are shown in dark green, while other MPAs not constituting fishing closures are shown in light green. C: Condor seamount; F: Formigas islets and bank; JC: D. João de Castro seamount; LS: Lucky Strike hydrothermal vent field; LU: LUSO hydrothermal vent field; MG: Menez Gwen hydrothermal vent field; S: Sedlo seamount.

Table 18. Proportion of the conservation features (Section 5.1) that are currently protected in the existing network of marine reserves in the "data-rich" spatial planning area of the Azores.

Feature	Feature description	% protected	Feature	Feature description	% protected
Commercially important deep-sea fish; HSM	*B. splendens*	2.1	CWC records	*E. dabneyi*	6.4
	P. kuhlii	5.0		*Leiopathes* spp.	19.4
	H. dactylopterus	3.3		*L. pertusa*	28.6
	P. americanus	1.6		*M. oculata*	23.1
	P. bogaraveo	4.6	Inferred VMEs	VME index	7.9
	B. decadactylus	2.8	Important areas	Important areas	29.1
Vulnerable deep-sea sharks and rays; HSM	*C. squamosus*	3.2	Depth class	0 to 600m	4.1
	C. coelolepis	0.7		600 to 800m	3.6
	C. owstonii	0.9		800 to 1200m	3.9
	C. crepidater	2.2		1200 to 2500m	1.2
	D. licha	3.9		Deeper than 2500m	0.2
	D. calcea	2.7	GMUs	Island shelf	27.93
	D. profundorum	4.6		Island shelf unit	4.15
	D. batis	2.0		High relief peak	8.67
	E. pusillus	6.4		High relief unit	3.30
	E. spinax	2.4		Low relief peak	0.07
	L. fullonica	0.5		Low relief unit	0.07
	S. laticaudus	4.8		Depression	0.29
Habitat-structuring CWC; HSM	*C. verticillata*	6.1		Hills	0.71
	P. josephinae	6.9		Flat area	0.40
	P. johnsoni	4.4			
	Coral garden	8.5			

5.2.2 Penalty for network properties

The configuration (i.e. number and size of individual clusters of PUs) of the network of closed areas is very important in systematic conservation planning design since it may have an effect on the achievement of the defined management goals, but also on the cost of implementation, surveillance, and ultimately in its success. Networks should be set based on recent guidelines for designing marine reserve networks for both conservation and fisheries management (e.g. Gaines et al., 2010). The majority of the MPAs worldwide are single and often isolated areas and based on the assumption that isolated MPAs must be self-persistent (Hastings & Botsford, 2006). However, this is highly dependent on the size and location of such MPAs as well as the management goals to be achieved. While large (> 100,000's km^2) single MPAs have the advantage of protecting the whole ecosystem and the variety of habitats within them (Wilhelm et al., 2014), small single MPAs do not often achieve the goals for which they were established mostly because they are unable to support self-sustaining populations (Roberts et al., 2001; Halpern, 2003). An advocated alternative is to build a network of connected MPAs that would help non-self-sustaining closed areas to receive and export sufficient biological material, and also achieve habitat representativity and replication (Gaines et al., 2010; Magris et al., 2018). The latest is of paramount importance to promote persistence and providing insurance against local failures or disasters (Allison et al., 2003). The relevance of considering biological connectivity in marine reserve planning is still under debate (Balbar & Metaxas, 2019; Costello & Connor, 2019; Manel et al., 2019) but recent studies suggest that combining representativity and connectivity objectives provides the best strategy for enhanced biodiversity persistence in the network of marine reserves (Baco et al., 2016; Magris et al., 2018; Manel et al., 2019).

Here, we used three configurations of priority areas design based on the size individual clusters of PUs (large, medium, and small). This was implemented in the prioritization approach by setting different values for the boundary penalty that penalises fragmented solutions using a matrix of shared boundary length between different PUs (Hanson et al., 2019). Increasing the boundary penalty tends to minimize the total boundary length of the conservation solution, thus reduces the number but increases the size of each individual conservation area, ultimately leading to very few large and isolated areas. Here, we developed three alternative scenarios with different boundary penalty values that would result in a range of clumping for the selected network:

- Low clumping scenarios, which are expected to produce many single and widely spread clusters of PUs, usually highly connected and replicated but costly to implement and enforce. These scenarios were implemented with a boundary penalty of $5 \cdot 10^{-7}$;
- High clumping scenarios, which on the opposite are expected to produce very few clusters of PUs, usually large, isolated, not replicated but probably representative, and easier to implement and to enforce. These scenarios were implemented with a boundary penalty of $5 \cdot 10^{-5}$;
- Medium clumping scenarios, which were built to have a compromise that would help satisfying most of the design criteria including the important resources, important areas, representativity, connectivity, replication, and viability and adequacy. These scenarios were implemented with a boundary penalty of $5 \cdot 10^{-4}$.

These values were chosen and regarded as a good range for obtaining an incremental clumping of solutions after a testing phase, where various penalty values were examined. Connectivity among priority areas were further addressed in the simplified prioritization solutions where we complemented the network with a representativity and connectivity approach (Section 0).

5.3 Cost model

It has been widely recognized that spatial planning needs to account for existing opportunity costs along with potential ecosystem function loss when designing planning scenarios (Naidoo et al., 2006). Thus, SCP can be designed so that management goals and objectives are considered while minimizing impacts on existing activities (i.e. avoiding areas of high fishing activity) and considering stakeholders interests (Douvere, 2008). Incorporating socioeconomic costs into SCP usually aims at minimizing the impacts on existing users, reduce conflicts between exploitation and conservation goals, and to produce cost-effective plans to implement and manage (Ban & Klein, 2009; Ban et al., 2013; Section 5.2.2). However, it has been argued that SCP scenarios should also be designed to address management goals and objectives regardless of the existing human activities (Baker-Médard et al., 2019). In this way, SCP can help to produce the best management scenarios for biodiversity conservation that could serve as a baseline for comparison with those that compromise between conservation and socio-economic cost.

In spatial prioritization approaches, the cost layer accounts for the cost that protecting each planning unit would imply (Ardron et al., 2010). Many possible conservation costs are usually enumerated including acquisition costs, management costs, implementation costs, compensation costs, and other socio-economic costs (Naidoo et al., 2006; McCrea-Strub et al., 2011; Ban et al., 2013). However, since the primary human activity occurring in the deep waters of the Azores is deep-water bottom fishing, we have only considered the opportunity costs originated from the deep-sea benthic fisheries (Morato, Fauconnet, Taranto, et al., unpublished data), namely from bottom longline and handline, and from drifting deep-water longline (Section 2.2.1). A measure of fishing effort was used as a proxy for the economic loss from fisheries caused by the creation of protected areas (Ban & Klein, 2009).

Submarine cables cross the Azores region, but they cover a reduced area and therefore were not considered essential to include in the prioritization approach (Appendix 1.5.5). Shipping was also not considered since this planning approach is mostly designed to explore different scenarios of fisheries closures only. However, shipping regulations may become necessary to implement when addressing conservation and management issues in the open ocean (Game et al., 2009). Finally, deep-sea was also not included in the prioritization approach since no commercial deep-sea mining exploration or exploitation contracts in the Azores have been signed. It should be noticed that most areas known to contain Seafloor Massive Sulphide (SMS) deposits lie within the Azores Marine Park as part of the PMA13 MPA (Section 2.2.2). However, they lack effective protection measures since deep-sea mining exploration activities are not prohibited.

Climate change has been recognized to severely affect the deep-sea (Section 2.2.3) and therefore should be considered in systematic conservation planning (Thresher et al., 2015; Dunn et al., 2018; Cheung et al., 2018; Combes et al., 2019; Levin et al., 2019). Prioritization approaches should account for climate change hazards (Levin et al., 2019), climate velocities (Brito-Morales et al., 2018), climate representative areas (Dunn et al., 2018), and species-specific climate refugia (Keppel et al., 2012; Morato et al., 2020). Unfortunately, the Coupled Models Intercomparison Project Phase 5 (CMIP5) outputs are only available at a 0.5° resolution. This resolution was demonstrated not to be suitable for predicting climate-driven changes in the environmental conditions at a regional scale such as that of the Azores. Therefore, the prioritization approaches presented here do not consider climate change.

5.3.1 Deep-water bottom fishing effort data

We used an updated version of the existing maps of predicted fishing effort in the Azores (Appendix 1.5), with greater detail to those assessing bottom longline and handline fisheries (Appendix 1.5.3). The bottom-fishing cost layer was computed from an analysis of the Vessel Monitoring System (VMS) for vessels licensed for bottom longline or handline fishing gears. The fishing licences granted to each vessel per year were used to allocate a gear type to all VMS pings. We acknowledge that not all boats operating in the spatial planning area (beyond 6 nm from island shores) have VMS systems installed. However, a quick comparison of the VMS outputs with the fishing effort maps obtained from fishers' inquiries (Diogo et al., 2015) revealed similar spatial patterns, but much more spatial detail when using the VMS data. In total, VMS data was obtained from 74 anonymous vessels over the period 2002-2018 with an average of 12 vessels per year. This number represents about 25% of the bottom longline fleet if considering an average of 52 vessels per year that declared landings using bottom longline.

After cleaning the VMS database, the derived speed, heading and change in angle were calculated based on the geographic positions of consecutive pings and used for subsequent analysis. The calculated variables better represent the behaviour of fishing vessels over the time between pings than the instantaneous values provided in the original VMS data. From the VMS pings, a new trip was identified if: i) the vessel was in the harbour (i.e. within a distance inferior or equal to 1.5 nm from a harbour), and at a calculated speed inferior or equal to the harbour speed (set to 0.5 knots), but the speed of the next ping was superior to the harbour speed, or if ii) the time difference between 2 consecutive pings was superior to 90 hours, and the next ping was outside of a harbour (i.e. further than 1.5 nm). A new leg was considered when the angle change between 2 consecutive calculated headings was superior to 50°, and the vessel was outside the harbour (distance >1.5 nm from any harbour). Only the major harbours in the Azores were considered.

We used heuristic methods to define the fishing vessels state at any given time using specific rules for speed, course, leg, angle, and distance to harbour. The preliminary results have been validated with a quasi-Bayesian approach (Glogovac et al., unpublished data). The vessels were considered "fishing" when i) the distance to the closest harbour was greater than 1.5 nm, ii) the leg did not finish or start in a harbour (distance greater than 1.5 nm), iii) the calculated speed was between 0 and 3 knots, iv) the length of the leg was between 0 and 15 nm, and v) it was later than 5 am, but earlier than 1 am. When conditions i to iv were met but between 1 and 5 am, the vessel was considered "resting/night". This time rule was implemented for bottom longliners to reduce the number of false positives and because, contrary to pelagic longlines, the resting state based on low speed was not adequate to distinguish from the fishing state. This is mostly true for those vessels operating with handlines. If the vessel was close to a harbour (i.e. at a distance inferior or equal to 1.5 nm), and at a slow speed (inferior or equal to 0.5 knots) it was considered "in harbour". "Steaming" was considered when i) the vessel speed was above the fishing speed (i.e. superior to 3 knots) or ii) the vessel was close to a harbour (at a distance inferior or equal to 1.5 nm) but at a faster speed than it would have if inside a harbour (i.e. superior to 0.5 knots) or, iii) the vessel was far from any harbour, and within fishing speeds, but a) the leg was starting or finishing in a harbour, or, b) the length of the leg was longer than 15 nm. Fishing effort was estimated as the sum of the time difference between pings associated with the fishing state.

5.3.2 Implementation of the planning unit cost

Two alternative scenarios based on different cost functions were considered. This approach aims to provide the option to 1) target areas with high conservation potential regardless of the fishing cost or 2) target areas with high conservation potential but reduced human activities. In the first case, the management goal would be to ***restore*** important but potentially impacted areas regardless of the cost. These scenarios may be considered the best solutions for achieving the management and conservation goals and objectives since the PUs with the higher potential for achieving the representation targets are favoured. In the second case, the goal would be to ***protect*** important but potentially less impacted areas and to reduce the socio-economic cost. The latter scenarios may be considered easier to implement due to its lower overlap with existing fisheries footprint. To implement these two types of scenarios, we used two different types of costs in prioritization:

- an area-based cost to minimize the network area necessary to achieve the representation targets (Section 5.4.1);
- a varying cost that was increased relative to the fishing effort (opportunistic cost) in order to minimize the amount of current fishing grounds areas in the network.

Area-based cost

The area-based cost was set to 1 for all the planning units. With this configuration, the prioritization relied only on conservation features and network properties (i.e. penalties). Thus, priority areas were selected by the Marxan algorithm upon their potential for contributing to the management goals, disregarding whether these areas may be economically important or may have been impacted by human activities.

Varying fishing cost

The sum of the fishing effort was calculated for each planning unit and year. PUs with a sum of fishing effort over the last 17 years smaller than 0.1% of the maximum value were excluded for being potential errors derived from the VMS data analysis. The sum of the fishing effort over the 2002-2018 period in each PU was log-transformed [$Log_{10}(x+1)$] and expressed as a relative effort index between 0 and 1 (Figure 41). Bottom longline fishing footprint covered about 2.6% of the total planning area but was mostly distributed on the "data-rich" area. The current fishing footprint represented about 7.4% of the "data-rich" area, covered almost all PUs shallower than 1,000m depth, and was distributed mostly in the seamount and banks south of Faial and Pico islands (Princesa Alice and Açor), on the shallow parts of the Mid-Atlantic Ridge (Gigante, Voador, Cavala, Ferradura, Monte Alto, and Sarda), around Terceira island and in Mar da Prata bank, South of São Miguel island (Figure 41). Only very few fishing events were identified in the "data-poor abyssal" area, but they may be the result of false positives from the VMS data analysis.

In order to set a cost value for the large majority of planning units that did not contain any fishing, the cost layer combined a "base" cost of 1, identical for all planning units, and a cost proportional to the fishing effort following the formula: Socioeconomic cost layer = $1+ 10*F_{effort}$. The fishing effort values were here multiplied by 10, so the PUs without fishing were kept at a low cost (1), while the PUs with fishing had a relatively high cost.

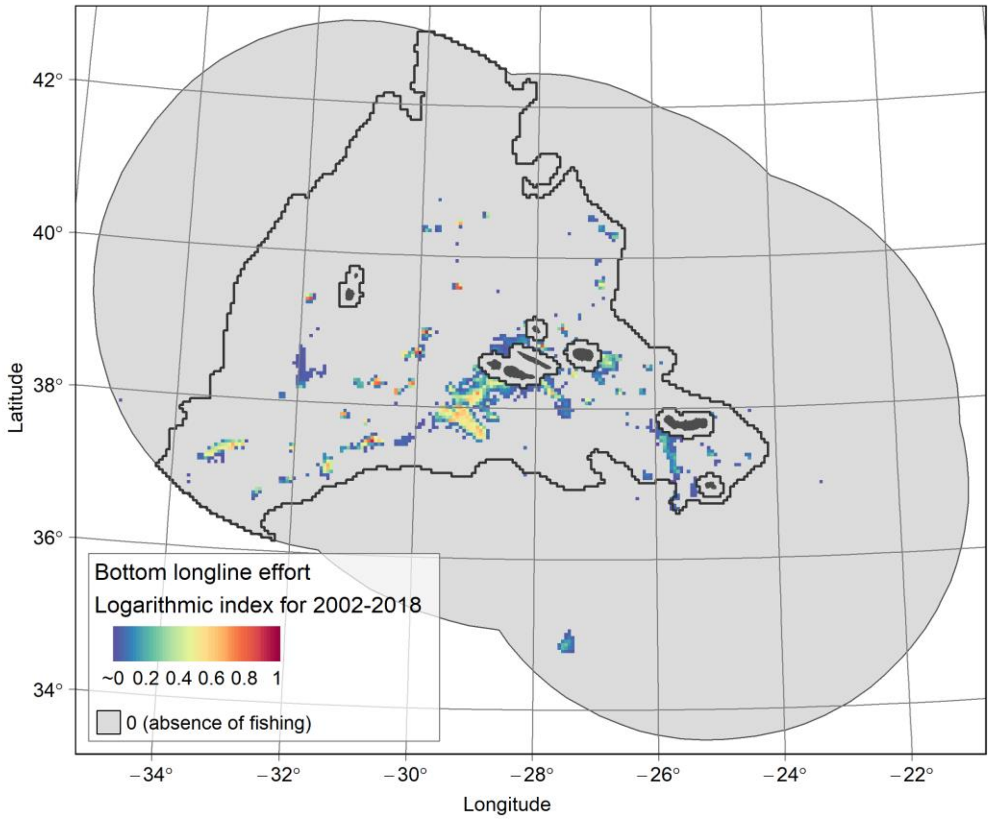


Figure 41. Bottom longline fishing in the EEZ of the Azores expressed as a logarithmic index of effort within the fishing footprint at the 5km resolution, based on the analyses of VMS data.

5.4 Prioritization targets

5.4.1 Spatial planning closure targets

Four targets determining the proportion of the spatial planning area to be included in the prioritization solutions were adopted based on international regulations and the scientific literature: 10%, 15%, 30 and 50%. First, the Convention on Biological Diversity (CBD) defined the Aichi Target 11, which calls for 10% of coastal and marine areas to be conserved by 2020 (Convention on Biological Diversity, 2010). Here we used 10% closure target as the lower limit of the spatial planning area to be included in the network. Second, we used the target of 15% closures target included in the Memorandum of Understanding signed between the Government of the Azores and Blue Ocean Foundation. Thirdly, the World Parks Congress (World Parks Congress, 2014) and the IUCN World Conservation Congress (IUCN World Conservation Congress, 2016) recommended the goal of protecting at least 30% of each marine habitat. More recently, at the 2018 UN General Assembly the UK Government called all nations to protect 30% of the oceans by 2030. Here, we used 30% as an intermediate spatial planning closure target. Finally, the scientific community has been evaluating the effectiveness of coverage targets for ocean protection and suggested that more than 30% should be protected (Gell and Roberts, 2003; Gaines et al., 2010; O'Leary et al., 2016), depending on species, habitats, pressures, and optimization objectives (White et al., 2017). Recently, discussions started around making half the Earth, including the Oceans, into a network of protected areas (Noss et al., 2012; Wilson, 2016) and very recently, several voices at the World Conservation Congress started to call for 50% coverage. Here, we used 50% as the higher spatial planning closure target.

5.4.2 Feature's representation targets

To achieve the desired spatial planning area closure targets, representation feature's targets were assigned to each feature (i.e. 0 to 100% of inclusion in the prioritisation solution). The prioritization approach algorithm finds the best solution, so individual features coverage targets are achieved within the all "data-rich" or "data-poor abyssal" planning areas and sub-regions. This allowed securing the same proportion of a conservation feature within each sub-region is included in the prioritization solution at the same time. The adoption of the sub-regions resulted in spreading the prioritization solutions across the whole spatial planning area, by identifying priority areas for conservation in all sub-region and not only in those areas with the highest density of features.

A series of decisions were adopted during the implementation process to define the representation targets:

- Features with a spatial coverage in the "data-rich" planning area lower than 10% (Figure 42) were assigned the overall target for the scenario (Table 19);
- Features with a spatial coverage in the "data-rich" planning area higher than 10% (e.g. some vulnerable deep-sea sharks; Figure 42) were assigned lower targets for the scenarios 30% and 50% (Table 19) because of their wide distributions and the likelihood that some habitat suitability models may have over-predictions;
- Targets for known occurrences of living colonies of cold-water coral defined as unique or rare, fragile, structurally important, or for having life-histories that make recovery difficult, were slightly increased to account for their reduced (Figure 42) and patchy distribution and their vulnerability (Table 19);
- Targets for the seabed habitats (i.e. GMUs considering environmental clusters) were adjusted based on their spatial coverage, perceived importance for abyssal and bathyal biodiversity on the degree of scientific knowledge to inform the prioritization (Table 19 and Table 20).

The resulting representation targets adopted for each scenario are summarized in Table 19 for the "data-rich" area and Table 20 for the "data-poor abyssal" area.

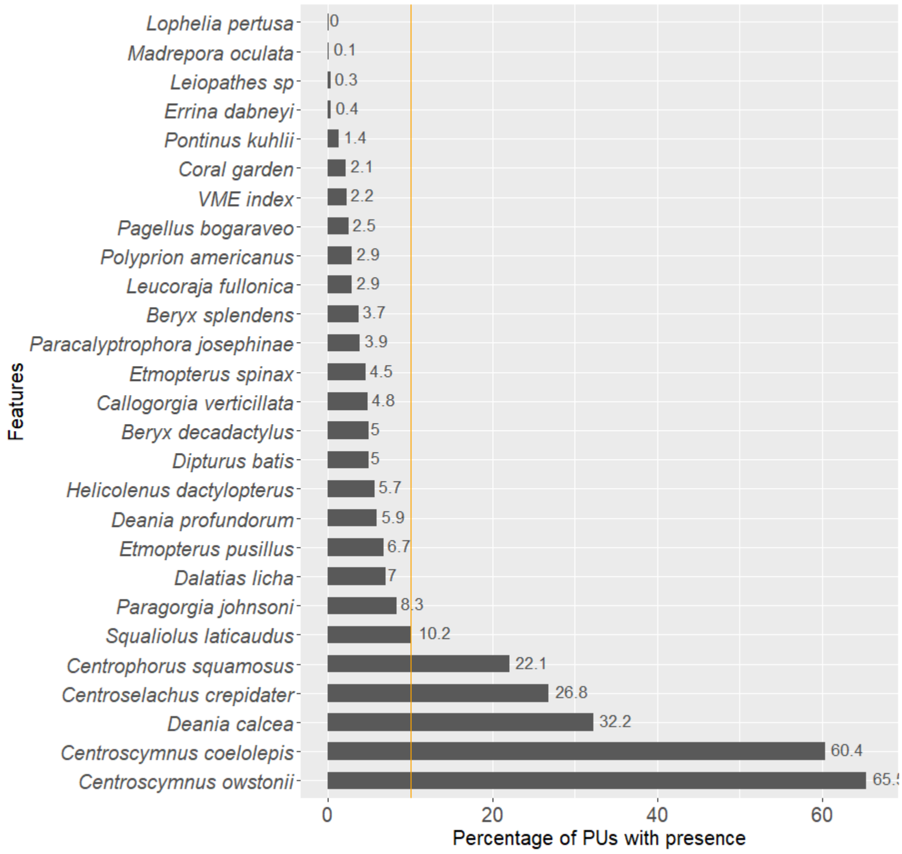


Figure 42. Percentage cover of the different features included in the prioritization approach in the "data-rich" area.

The target for the seabed habitats were adjusted to their spatial coverage in the "data-rich" area (Table 19):

- GMUs with low coverage in the "data-rich" area (<5%; IS, IS-U, HR, HR-U, LR, and LR-U) (Table 21) were assigned targets similar to the spatial planning closure target; i.e., 10%, 15%, 30%, and 50% (Table 19);
- GMUs with medium coverage in the "data-rich" area (5-15%; D, and HI) (Table 21) were assigned a 10% for the 10% scenario and 15% for all other scenarios (Table 19);
- The flat areas have a very large coverage in the "data-rich" area (73%; FA) (Table 21) but almost no scientific data to inform the prioritization, and therefore the targets were set to 1.7% for the 10% scenario and 2.5% for all other scenarios (Table 19).

Since the information was considered to be inadequate in the abyssal plains (flat areas) of the "data-rich area", we have complemented the prioritization approach with a representativity approach design to identify representative areas of all seabed habitats and to achieve the prioritization targets.

The target for the seabed habitats were also adjusted to their spatial coverage in the "data-poor abyssal" area (Table 20):

- GMUs with low coverage in the “data-poor abyssal” area (<5%) (Table 21) and with a perceived great importance for abyssal and bathyal biodiversity (Section 5.1.7; high relief HR and HR-U) were prioritized by setting an 80% target (Table 20);
- GMUs with low coverage (<5%; Table 21) in the “data- poor abyssal” area (LR and LR-U) were assigned targets similar to the spatial planning closure target; i.e, 10%, 15%, 30%, and 50% (Table 20);
- GMUs with medium coverage (5-15%; Table 21) in the “data-rich” area (D, and HI) were assigned a 10% for the 10% scenario and 15% for all other scenarios since no scientific data exists to inform the prioritization (Table 20).
- Flat areas were not prioritized in the “data-poor abyssal” area since they cover the vast majority of the planning area (approx. 83%; Table 21), no scientific data exists to inform the prioritization, and they are unlikely to be impacted by direct human activities.

Given these representation targets, the representativity management goal would require up to 12.4% of both the “data-rich” and 4.1% of the “data-poor abyssal” areas (Table 21). Since the information was considered to be inadequate or insufficient to justify a full data-driven approach in the “data-poor abyssal”, we have complemented the prioritization approach with a representativity approach design to identify representative areas of all seabed habitats and to achieve the prioritization targets.

Table 19. Management and representation targets for all features prioritized in the "data-rich" planning area in the different systematic conservation planning scenarios.

Feature	Feature description	Type	Criteria	Scenario 10%	Scenario 15%	Scenario 30%	Scenario 50%
Commercially important deep-sea fish	*Beryx splendens*	HSI	<10%	0.10	0.15	0.30	0.50
	Pontinus kuhlii	HSI	<10%	0.10	0.15	0.30	0.50
	Helicolenus dactylopterus	HSI	<10%	0.10	0.15	0.30	0.50
	Polyprion americanus	HSI	<10%	0.10	0.15	0.30	0.50
	Pagellus bogaraveo	HSI	<10%	0.10	0.15	0.30	0.50
	Beryx decadactylus	HSI	<10%	0.10	0.15	0.30	0.50
Vulnerable deep-sea sharks and rays	*Centrophorus squamosus*	HSI	>10%	0.10	0.15	0.15	0.30
	Centroscymnus coelolepis	HSI	>10%	0.10	0.15	0.15	0.30
	Centroscymnus owstonii	HSI	>10%	0.10	0.15	0.15	0.30
	Centroselachus crepidater	HSI	>10%	0.10	0.15	0.15	0.30
	Dalatias licha	HSI	<10%	0.10	0.15	0.30	0.50
	Deania calcea	HSI	>10%	0.10	0.15	0.15	0.30
	Deania profundorum	HSI	<10%	0.10	0.15	0.30	0.50
	Dipturus batis	HSI	<10%	0.10	0.15	0.30	0.50
	Etmopterus pusillus	HSI	<10%	0.10	0.15	0.30	0.50
	Etmopterus spinax	HSI	<10%	0.10	0.15	0.30	0.50
	Leucoraja fullonica	HSI	<10%	0.10	0.15	0.30	0.50
	Squaliolus laticaudus	HSI	>10%	0.10	0.15	0.15	0.30
	Callogorgia verticillata	HSI	<10%	0.10	0.15	0.30	0.50
Habitat-structuring CWC	*Callogorgia verticillata*	HSI	<10%	0.10	0.15	0.30	0.50
	Paracalyptrophora josephinae	HSI	<10%	0.10	0.15	0.30	0.50
	Paragorgia johnsoni	HSI	<10%	0.10	0.15	0.30	0.50
	Coral garden	HSI	<10%	0.10	0.15	0.30	0.50
CWC records	*Errina dabneyi*	Records	Increased	0.15	0.30	0.50	0.80
	Leiopathes spp.	Records	Increased	0.15	0.30	0.50	0.80
	Lophelia pertusa	Records	Increased	0.15	0.30	0.50	0.80
	Madrepora oculata	Records	Increased	0.15	0.30	0.50	0.80
Inferred VMEs	VME index	Index	<10%	0.10	0.15	0.30	0.50
GMUs	Island shelf	Habitat	Low cover	0.10	0.15	0.30	0.50
	Island shelf unit	Habitat	Low cove	0.10	0.15	0.30	0.50
	High relief peak	Habitat	Low cover	0.10	0.15	0.30	0.50
	High relief unit	Habitat	Low cover	0.10	0.15	0.30	0.50
	Low relief peak	Habitat	Low cover	0.10	0.15	0.30	0.50
	Low relief unit	Habitat	Low cover	0.10	0.15	0.30	0.50
	Depression	Habitat	Med. cover	0.10	0.15	0.15	0.15
	Hills	Habitat	Med. cover	0.10	0.15	0.15	0.15
	Flat area	Habitat	Large cover	0.017	0.025	0.025	0.025

Table 20. Management and representation targets for all features prioritized in the "data-poor abyssal" planning area in the different systematic conservation planning scenarios.

Feature	Feature description	Type	Criteria	Scenario 10%	Scenario 15%	Scenario 30%	Scenario 50%
GMUs	High relief peak	Habitat	Low cover and perceived great importance	0.80	0.80	0.80	0.80
	High relief unit	Habitat	Low cover and perceived great importance	0.80	0.80	0.80	0.80
	Low relief peak	Habitat	Low cover	0.10	0.15	0.30	0.50
	Low relief unit	Habitat	Low cover	0.10	0.15	0.30	0.50
	Depression	Habitat	Med. cover	0.10	0.15	0.15	0.15
	Hills	Habitat	Med. cover	0.10	0.15	0.15	0.15
	Flat area	Habitat	Large cover but no info	-	-	-	-

Table 21. Seabed typology classes coverage on the planning area and representation target.

Class code	Name	N of environmental clusters	Total area (km^2)	Total cover (%)	"Data-rich" area			"Data-poor abyssal" area		
					Cover (%)	Max. target (%)	Max. target Cover (%)	Cover (%)	Max. target (%)	Max. target cover (%)
IS	Island shelf	2	1,223	0.13	0.39	50	0.20	0	-	-
IS-U	Island shelf unit	3	5,288	0.56	1.65	50	0.83	0	-	-
HRP	High relief peak	3	6,324	0.67	1.54	50	0.77	0.23	80	0.18
HR-U	High relief unit	3	28,933	3.07	6.89	50	3.45	1.11	80	0.89
LR	Low relief peak	6	3,106	0.33	0.37	50	0.19	0.31	50	0.16
LR-U	Low relief unit	6	14,328	1.52	1.59	50	0.80	1.48	50	0.74
D	Depression	4	90,049	9.54	13.72	15	2.06	7.4	15	1.11
HI	Hills	2	98,127	10.40	17.9	15	2.69	6.56	15	0.98
FA	Flat areas	2	695,730	73.70	55.93	2.5	1.40	82.78	-	-
TOTAL		31	943,108	100	100	-	12.36	100	-	4.06

5.5 Planning scenarios

For the overarching goal of restoring fish stocks of commercially important deep-sea benthic species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores EEZ, we developed twenty-four different systematic conservation planning scenarios and assessed the performance of the each of them (Table 22). These scenarios considered:

- four different targets for the proportion of the spatial planning area to be included in the prioritization solutions (10%, 15%, 30%, and 50%),
- three different configurations of priority areas for management and conservation design (high, medium, and low clumping), and
- two cost models (fishing cost, targeting areas with high conservation potential but low fishing activities; area-based cost, targeting areas with high conservation potential regardless of existing human activities).

Additionally, we developed twelve scenarios (Supplementary information Section 14.1) to address only the 1) restoring fish stocks of commercially important deep-sea benthic species, or 2) ensuring protection of intact and restoration of degraded Vulnerable Marine Ecosystems. As stated before, these alternative scenarios aimed at evaluating how different management goals and objectives can influence the prioritization outputs. For each of these alternative management goals only six systematic conservation planning scenarios and performance assessments were developed:

- one target for the proportion of the spatial planning area to be included in the prioritization solutions (30%),
- three different configurations of closed areas (high, low and medium clumping), and
- two cost models (fishing cost and area-based cost).

The spatial prioritization approach combined both the "data-rich" and "data-poor abyssal" areas by attributing features and representation targets to both of the areas at the same time. For the "data-rich" area information on important resources, important areas, and habitat representativity were used, while for "data-poor abyssal" area only habitat representativity was considered.

Table 22. Summary of the conservation planning scenarios developed for the Azores deep sea.

Scenarios	Overarching goals	Features	Planning area	Area targets	Network clumping	Cost	N of outputs
Main scenario	Restoring fish stocks of commercially important deep-sea benthic species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities	• Important areas • 5 commercially important deep-sea fishes • 12 vulnerable deep-sea sharks and rays • 9 habitat-structuring CWC • Inferred VMEs • 8 GMUs	• "Data-rich" & • "Data-poor abyssal" combined	• 10% • 15% • 30% • 50%	• low • medium • high	• Area-based • Fishing	4 area targets * 3 clumping * 2 costs = 24
Commercial fish (Sup. Info. Section 14.1.1)	Restoring fish stocks of commercially important deep-sea benthic species	• Important areas • 5 commercially important deep-sea fishes	• "Data-rich"	• 30%	• low • medium • high	• Area-based • Fishing	2 costs * 3 clumping = 6
VMEs (Sup. Info. Section 14.1.2)	Ensuring protection of intact and restoration of degraded Vulnerable Marine Ecosystems.	• Important areas • 9 habitat-structuring CWC • Inferred VMEs	• "Data-rich"	• 30%	• low • medium • high	• Area-based • Fishing	2 costs * 3 clumping =6

5.6 Solving

The different prioritisation problems were solved with the Gurobi solver (Gurobi Optimization LLC, 2018). Each scenario was solved once so the first solution (i.e. less costly solution to achieve all the representation targets) was returned. Conservation problems were parametrized with a binary decision that is either to protect (output value of 1) or not to protect (output value of 0) each PU. For each scenario, different maps were generated to display different aspects:

- A "solution" map exhibiting the locked-in PUs (important areas) and the selected priority areas for conservation;
- A "species richness" map exhibiting the number of species (including the VME index) occurring in selected priority areas for conservation. The areas with a 0 value contained only GMUs and accounted mostly for the representativity management goal;
- A map exhibiting the selected priority areas for conservation that aim to: 1) "protect" areas outside the present bottom fisheries footprint, thus likely not impacted by fishing and with low cost; or 2) "restore" areas inside the present bottom fisheries footprint, thus likely most impacted by fishing and with higher cost.
- A "fishing effort" map exhibiting the BLL effort value in selected priority areas for conservation, thus allowing to identify the areas in the network that contained the highest effort.

5.7 Performance assessment

The performance of the planning scenarios was assessed against the six design criteria following different metrics (Table 23). In summary:

- **Viability and Adequacy**: this criterion was assessed by the different proportion of the area covered by the priority areas selected;
- **Replication**: we assessed this criterion by the number of closed areas in each scenario.
- **Connectivity**: we evaluated this criterion by estimating the average and the maximum distance between priority areas, the proportion of isolated areas, and the proportion of highly connected areas;
- **Representativity**: we assessed this criterion by evaluating the proportion of the depth strata, seabed habitats, and seamounts inside the priority areas;
- **Important resources**: we have assessed this criterion using the proportion of the predicted habitat suitability index, abundances, and other indexes inside the priority areas, as well as the average habitat quality or confidence inside the priority areas.
- **Important Areas**: since important areas were always locked-in, they were included in all solutions and therefore no performance assessment was required;
- **Resilience to climate change and other stressors**: this design criterion was not implemented and therefore not assessed.

Table 23. Performance assessment metrics for evaluating the planning scenarios against the six design criteria

Design criteria		Variable
Viability and adequacy	Priority areas outputs	Size of the network (1,000 km^2)
		Proportion of the spatial planning area in the solution
		Proportion of the spatial planning closure targeted area achieved
		Proportion of priority areas in the "data-poor abyssal" area
		Average size of priority areas
		Proportion of the network that is already protected
		Proportion of the fishing footprint in the network
		Proportion of the total fishing effort in the network
Replication	Priority areas outputs	Number of priority areas
		Number of priority areas larger than 100km^2
Connectivity	Priority areas outputs	Average distance to closest neighbour (km)
		Maximum distance to closest neighbour (km)
		Proportion of isolated priority areas (dist. >100km)
		Proportion of total network area that is isolated
		Proportion of highly connected priority areas (≥10 neighbours, ≤ 100km)
		Proportion of total network area that is highly connected
Representativity	Depth strata	Proportion of depth class in the solution
	Seabed habitats	Proportion of each seabed class in the solution
		Number of GMUs that achieved the spatial planning target
	Seamounts	Proportion of shallow (0-800m), medium (800-1500m) and deep (>1500m) seamounts in the solution
Important resources	Commercially important deep-sea fish	Proportion of the habitat suitability index (averaged for all species) in the solution
		Proportion of the predicted suitable habitat (averaged for all species) in solution
		Average suitability index in solution (proportion of max.)
		Average of the proportion of the total predicted abundance selected in solution (5 species)
		Proportion of suitability index in/out the fishing footprint
	Vulnerable deep-sea sharks and rays	Proportion of the habitat suitability index (averaged for all species) in the solution
		Proportion of the predicted suitable habitat (averaged for all species) in solution
		Average suitability index in solution (proportion of max.)
		Average of the proportion of the total predicted abundance selected in solution (4 species)
		Proportion of suitability index in/out the fishing footprint
	Inferred habitat-structuring CWC	Proportion of the habitat suitability index (averaged for all species) in the solution
		Proportion of the predicted suitable habitat (averaged for all species) in solution
		Average suitability index in solution (proportion of max.)
		Proportion of suitability index in/out the fishing footprint
	Observed habitat-structuring CWC	Proportion habitat-structuring CWC records in network
		Proportion of the CWC records outside the fishing footprint
		Proportion of the CWC records inside the fishing footprint
	Inferred Vulnerable Marine Ecosystems	Proportion of the predicted total VME index in solution
		Average VME index value in solution (proportion of max.)
		Proportion of the VME index in/out the fishing footprint

5.8 Forecasting ecosystem-level outcomes

The overall benefits of marine reserves as fisheries management tools encompasses enhanced biodiversity, species abundance, fish size and fecundity that are expected to be exported to adjacent waters via ecological spillover effects (net emigration of juvenile and adult fish and/or larval exports). Ecological spillover is, in turn, expected to sustain surrounding fisheries and ultimately payback the loss of fishing grounds (fishery spillover; Gell & Roberts, 2003; Halpern et al., 2009; Goñi et al., 2010; Russ & Alcala, 2011; Kerwath et al., 2013; Di Lorenzo et al., 2016). Quantitatively, such "reserve effects" are typically translated into doubled densities, nearly tripled biomasses and 20 to 30% increases in the size and diversity of organisms, relative to neighbouring unprotected areas (Halpern, 2003; Sale et al., 2005). The extent of "reserve effects" thus influences ecological and fishery spillover phenomena.

However, there has been a longstanding debate on the wider effects of marine reserves on the ecosystem and adjacent fisheries (Roberts et al., 2001; Hilborn et al., 2004; Pendleton, et al., 2018). Besides the widely recognized positive effects of fisheries closures (Roberts et al., 2001; Edgar et al., 2014; Marshall et al., 2019), it has been argued that such the implementation alone may not be useful to protect or rebuild fish stocks and harvests (Allison et al., 1998; Barnes & Sidhu, 2013). For example, increased fishing pressure on stocks outside the closed areas may produce net negative effects on fisheries stocks and, therefore, the implementation of such closed areas will require a reduction in fishing effort and catch (e.g. through the reduction of total allowable catch TAC) (Hilborn et al., 2006). It is, therefore, of paramount importance to evaluate or project the economic and ecosystem effects of the implementation of area-based management tools.

Time-bounded ecosystem responses to networks of marine protected areas are not suitable to be explored through spatial optimization routines, as Marxan, but ecosystem modelling approaches (Watson et al., 2000; Pitcher et al., 2002). These tools capture the structure and functioning of marine food-webs to ultimately evaluate potential responses of ecosystem dynamics to scenarios of fishing pressures and environmental conditions.

Here, we adopted a framework that links Marxan approaches and a validated spatially-oriented ecosystem-based model of the Azores deep-sea, to evaluate ecosystem-level trade-offs associated with the implementation of different management tools, including fisheries closures. Briefly, the outputs of the systematic conservation planning approach were transferred into the spatially-oriented ecosystem model to forecast the effects of such management measures in the whole ecosystem. The simulations of the ecosystem effects of implementing area-based management tools were complemented with the evaluation of additional management strategies, as reductions on fishing effort of deep-sea fishing fleets (Cabral et al., 2019).

The overarching goal of the ecosystem-based assessment was to assess which scenarios maximize the achievement of ecosystem-based management goals and objectives (conservation and fisheries), embedded in the overarching mission of sustainable use of natural resources. We also aimed at assessing the performance of the systematic conservation planning scenarios achieving quantitative targets of "reserve effects" described above and ultimately understand to which extent network attributes (i.e., size, design) influence the magnitude of such effects. Given the principles of the ecological modelling approach and data availability to parametrize and validate the ecosystem model, focus was given to the objective of *rebuilding fish stocks of commercially important deep-sea benthic species to those levels prior to 1990's by 2040*.

5.8.1 Ecosystem modelling framework

The spatial-temporal ecosystem model of the Azores was developed with Ecospace, the space-time module of the Ecopath with Ecosim ecosystem modelling framework, under the Regional Government of the Azores projects 2020-Towards ecosystem-based management of the Azores marine resources, biodiversity and habitats (M2.1.2/I/026/2011) and MapGES (Acores-01-0145-FEDER-000056), and the European Union's Horizon 2020 projects, DiscardLess (No 633680) and ATLAS (No 678760).

The Ecopath with Ecosim and Ecospace toolbox (e.g., Christensen and Walters 2004, Walters et al., 1999) has been widely used to analyse ecosystem impacts to fishing activities at different scales. The Ecopath module provides a representation of the ecosystem through energy flows among the functional groups and species (biomass pools) that characterize a marine food-web, at a static point in time. The framework sets on mass-balanced principles to allocate production, among fishing, predation and other types of mortality, and migration between biomass pools. Ecopath provides the initial state for dynamic modelling (details on the underlying modelling theory, assumptions and equations are available on Walters et al., 1999; Christensen & Walters 2004; Christensen et al., 2008).

Using Ecosim, temporal changes in the biomass balanced in Ecopath in response to fishing drivers can be simulated at monthly time-steps. This dynamic component of the approach uses differential equations to predict changes in the biomass, under the form of consumption minus losses to predation, fishing, and migration events. Here, consumption is modelled following the principles of the foraging arena theory, described in Ahrens et al. (2012). The impact of external drivers in the stability of the food-web, such as regime shifts, can also be modelled.

Finally, Ecospace was designed to address spatial-oriented ecosystem questions (Walters et al., 1999; Pauly et al., 2000; Walters et al., 2010; Fouzai et al., 2012), such as evaluation of trade-offs related to the implementation of MPAs in exploited systems. The module projects fractions of biomass, balanced in Ecopath for each functional group, to a two-dimensional grid of equally sized cells (basemap) wherein groups execute random and symmetric movements (Walters et al., 1999). Modified versions of Ecosim's differential equations are then computed in each cell, simulating biomass temporal changes and species consumption that impact predator-prey relationships, at the local scale, in monthly time steps (Walters et al., 2010). Grid cells can be closed to fishing to evaluate resulting trophic cascades effects from the protection of top-predators within MPAs. Although the baseline dynamic of Ecospace derives from the underlying Ecopath with Ecosim models, it requires extra input data to add the spatial feature into the food-web (e.g., physical attributes of the study area, habitat preferences, and movement rates).

5.8.2 The ecosystem model of the Azores deep-sea environments (Ecopath)

A balanced Ecopath model describing the marine ecosystem of the Azores (Morato et al., 2016) was used as a baseline for the Ecospace model. This model provides a snapshot of the ecosystem in the year 1997, representing the food-web by 45 functional groups: a detritus group, two primary producer groups, eight invertebrate groups, 29 fish groups, three marine mammal groups, a turtle and a seabird group. This version of the model gives emphasis to the deep-sea benthic ecosystem, as 11 of the fish groups are single species of high commercial value, primarily targeted by the bottom longline fishing fleet (*Pagellus bogaraveo*, *Helicolenus dactylopterus, Mora moro, Phycis phycis*, *Lepidopus caudatus*, *Conger conger, Pontinus kuhlii, Raja clavata, Pagrus pagrus, Beryx splendens and Beryx decadactylus*). The model considered twelve fishing fleets, including those from Portugal mainland and foreign countries that operate in the Azores EEZ, targeting large pelagic fish. Model results highlighted the important roles of cephalopods, pelagic sharks and toothed whales in the structure of the

Azores marine ecosystem. The model was built with source data of an overall reasonable quality, especially considering the normally low data availability for deep-sea ecosystems. However, biomass estimates for most functional groups derived from the mass-balanced equations, which constitutes a notable limitation of the model. This pitfall has significant implications. For instances, the model estimated a fishing mortality rate of *Pagellus bogaraveo* much lower than what has been estimated by fisheries stock assessment models (Pinho et al., 2014).

5.8.3 Temporal dynamics of the Azores deep-sea ecosystem (Ecosim)

Using Ecosim, the Ecopath model was driven in time to simulate changes of fishing pressure on different ecosystem components, from 1997 to today (Lemey, 2013; Savina-Rolland et al., 2019). Time-series of fishing effort were used to drive the model temporally. Effort estimates for the bottom-longline & handline fishing fleet corresponded to the number of hooks times the number of landing events per year. Reference data of absolute catch and relative biomass were used to calibrate the model and evaluate its performance in replicating ecosystem trends (Heymans et al., 2016). Catch-time series were based on total catches in the Azores (illegal, unreported, unregulated), for all exploited functional groups included in the model, based on estimates described in Pham et al. (2013) and Fauconnet et al., (2019a). The relative biomass time-series were calculated using Relative Population Number (RPN) data, assessed through fisheries-independent Azorean Spring bottom longline surveys (sampling design described in Menezes et al., 2006). The hook and line method characteristic of the survey is associated with large bias on biomass estimates, and therefore low confidence is attributed to the time-series. Abundance data was only available for the important targets of the bottom longline & handline fleet (*Pagellus bogaraveo, Conger conger, Helicolenus dactylopterus, Mora moro, Phycis phycis*, *Pontinus kuhlii, Raja clavata, Pagrus pagrus, Beryx splendens, Beryx decadactylus,* large-size demersal fish - representative species *Polyprion americanus*, large-size shallow water fish - representative species *Serranus atricauda*, medium-size shallow water fish – representative species *Pagellus acarne* and Benthic sharks and rays – representative species *Galeorhinus galeus*).

The *fitting to time-series* process in Ecosim aims at calibrating key model parameters to maximize the goodness-of-fit between model predictions and reference data. Due to a recognized limitation in satisfactorily fitting the Azores Ecosim model to both biomass and catch time-series data using a single model (Savina-Rolland et al., 2019; Soszinksy et al., in prep.), the fitting procedure of the temporal dynamic model underlying Ecospace emphasised 90% on the biomass time-series and 10% on the catch time-series (corresponding to a "biomass-model"). This pitfall is related to the lack of accuracy associated with the time-series data used to drive, calibrate and validate the model.

The best practise guidelines for fitting Ecosim models were followed (Heymans et al. 2016) and encompassed the search for a time-varying productivity function ("forcing function") and the calibration of a vulnerability parameter that controls the amount of prey biomass available for predator consumption in the foraging arena. The forcing function corresponds to a primary production anomaly that multiplies the Ecopath production/biomass ratio of primary producers to represent regime shifts in the ecosystem. The shape of the "forcing function" was estimated with the Ecosim model to maximize the goodness-of-fit between model predictions and reference data. The Ecosim's vulnerability parameter multiplies the baseline predation mortality rates set in Ecopath to represent the maximum predation mortality rate that high predator biomasses can exert on a prey item. Due to difficulty of setting this parameter based on field observations, it is estimated under a *fitting to time-series* routine included in Ecosim, that first selects the most sensitive predator-prey interactions (v_{ij}) and then searches for the value that maximizes model's goodness-of-fit. Low vulnerability values ($v_{ij}<2$) represent bottom-up controls and prevent biomass gains in the predator. High values ($v_{ij}>2$) simulate top-down controls, where smooth increases in predator's biomass lead to high consumption rates. Implicitly, groups for which high vulnerabilities are estimated, exhibit high sensitive to fishing pressure. Among the benthic commercially important fish species, and based on the Ecosim model underlying Ecospace, top-down controls were estimated for *Pontinus kuhlii* and *Phycis phycis* (v_{ij}>10).

Ecosim model results highlighted that since the reference year of 1997, fishing effort had promoted oscillations in the biomass of the Azores ecosystem. Yet, fishing pressure (modelled through fishing effort time-series) and trophic interactions (modelled through predator-prey vulnerabilities) were not suitable to fully explain the temporal variability observed in the indices of relative biomass of key fish species (estimated by annual fisheries surveys). This result reinforces the considerable uncertainty associated to the annual fishing effort estimates, as they do not reflect technological advances in fisheries and improved catchability (the relationship between the catch rate and the population size) observed since the reference year.

Environmental variability (modelled through estimated time-varying productivity function) was concluded to be the driver that could better explain observed ecosystem trends. Lagged values of environmental factors acting at the Azores regional scale and broadly in the Atlantic seem to underpin the shape of estimated "forcing function" (Soszinksy et al., in prep.). The Ecosim model resembles good fit hindcasting temporal oscillations of biomass for most of the groups/species with time-series data. Yet, the model also presents weakness replicating trends for some species, that can be related to the model itself or to the time-series.

5.8.4 The spatial-temporal ecosystem-based model of the Azores deep-sea environments (Ecospace)

The Azores Ecospace model expands the ecosystem model at a spatial-temporal dimension (Brito, 2016). Its spatial boundary includes 9542 water cells, at 10 km resolution, in latitude and longitude, covering the full extent of the Azores EEZ (Figure 43). Habitat heterogeneity of the study area was introduced by bathymetry layers (in meters; Peran et al., 2016), Euclidean distance to coast (in nautical miles), and sea surface temperature (SST, in ºC; Amorim et al., 2017). Additionally, each cell was allocated to seven habitat-types, based on depth-strata and proximity to coast (island buffer); designed to broadly represent distribution patterns of fish assemblages and fishing activities (Figure 43). Furthermore, relative preferences of functional groups for the habitat attributes were set under a habitat foraging capacity model (Christensen et al., 2014) that differentiates the ability of groups to thrive under local environmental conditions. Within cells that represent low foraging capacity for a species (i.e., deep-sea cells for a shallow-water species), its biomass moves faster among grid cells, it is more vulnerable to predation and feeds at a lower rate. Habitat suitability functions deriving from species distribution modelling techniques (GAMs, Hastie & Tibshirani, 1990) linked the distribution of single species of high commercial value and others (e.g., Dolphins, Seabirds, Deep-sea sharks, Pelagic Sharks) to the depth, distance to coast and SST maps (e.g., Das, unpublished data; Amorim et al., 2009, Tobeña et al., 2016). For other functional groups, habitat preferences were simply set by binary allocation (presence-absence) to the depth and coastal habitat-types, based on their biology and ecology. Dispersal rates ($km \cdot year^{-1}$) for each functional group, capturing differences among movement patterns (i.e., swimming speed) of representative species of model functional groups were set, whenever possible, based on tagging data.

Ecospace spatially distributes fishing effort levels, inherited from Ecosim's time-series, over grid cells opened to fishing, based on a spatial economic model that balances expected incomes and costs associated to fishing in a particular cell (Walters et al., 1999; Christensen et al., 2008). To estimate cell catch and revenues, a *gravity model* was set-up taking into account the local biomass available for fishing, the ex-vessel price for each species (€ kg^{-1}), the catchability and the sailing cost proportional to the distance from ports in the eastern and central group of islands (Figure 43).

The shift from the Ecopath with Ecosim modules into Ecospace, enhances uncertainty and overall complexity of the model, as spatially-oriented parameters regulating the distribution of biomass pools and fishing effort are tuned. Significant efforts have been made in the last years to validate the Azores Ecospace model at its temporal and spatial components - an analysis that represents one of the major challenges of ecosystem-based models and modelling frameworks, including Ecospace. A notable pitfall of older versions of the Azores spatial model was the low performance to replicate relative abundance trends of commercial species, unlike the underlying Ecosim (Brito, 2016). The recent explicit integration of space-time data in the food-web, driving the biomass of primary producers, has allowed to overcome this limitation.

The Azores Ecospace model satisfactorily fits the relative biomass time-series of commercial important species, acknowledging the structural weaknesses of the food-web model and the approach itself. At the spatial domain, the model resembles biomass patterns that agree with Generalized Additive Models, developed *a priori* for some deep-sea commercial species (Parra et al., 2017). Besides, the Azores Ecospace model predicted hotspots of fishing effort, in agreement with Vessel Monitoring System (VMS) data from bottom longline and handline and pelagic fleets (Morato, Fauconnet, Taranto, et al., unpublished data). However, the model fails in simulating fine-scale patterns, particularly for the pelagic fleets, around eddies and frontal zones, likely due to inaccurate biomass distributions of the pelagic species. It has been concluded that the Azores Ecospace model is fit to evaluate ecosystem-based management strategies; mostly in what concerns to the deep-sea environments.

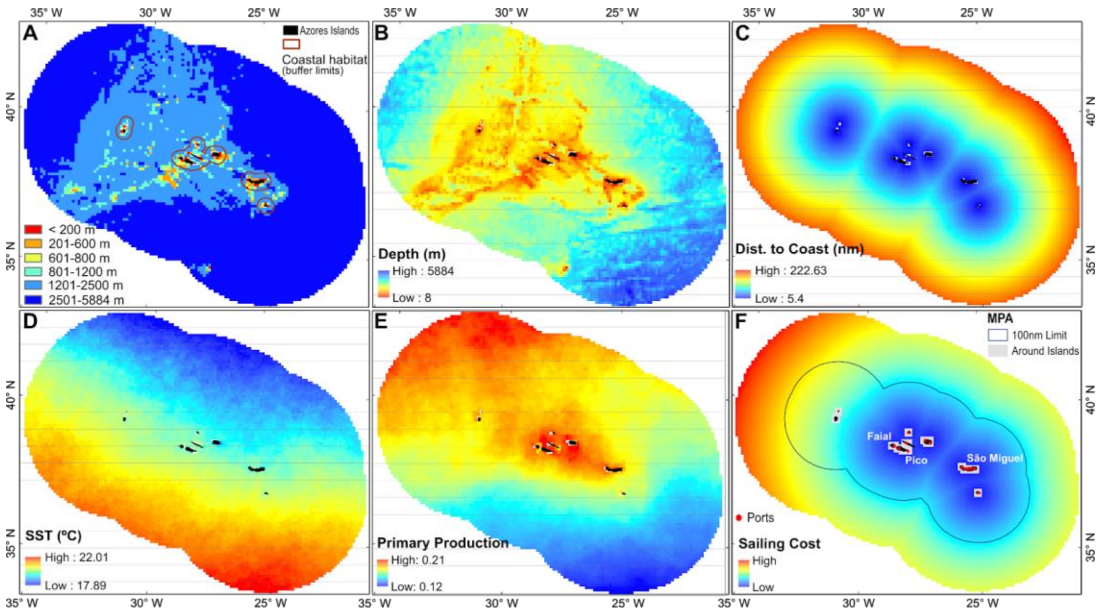


Figure 43. Initialization maps of A) habitat-types, B) depth (meters), C) distance to coast (nautical miles) D) sea surface temperature (ºC), E) primary production (mg Chl-a km^{2}·year^{-1}), and F) relative cost of sailing and MPAs (100nm – foreign fleet EC 1954/2003; around islands – pelagic fleets, drifting longliners and trawling EC 1568/2005), driving the Ecospace model of the Azores.

5.8.5 Evaluation of ecosystem and fisheries outcomes in response to management scenarios

The Azores Ecospace model was used to forecast ecosystem and fisheries effects over the following twenty years, in response to multiple management schemes, resulting from the implementation of the twenty-four systematic conservation planning scenarios (four spatial planning closure targets, three configurations of network design, i.e. clumping, due cost-models). Changes on biomass, catch and trophic-level indicators, were used as metrics to evaluate different responses to management strategies and respective scenarios. Model outcomes emphasised on deep-sea benthic fish species of high commercial value targeted by bottom longline and handline fleet and fitted to biomass and catch time-series data. The performance of multiple scenarios was addressed under four main management strategies that considered alternative levels of fisheries closures and fishing effort:

- ***Implementation of fisheries closed areas - MPA strategy***

  Forecasts resulting from the implementation of the twenty-four systematic conservation planning scenarios as no-take areas for bottom fishing gears (bottom longline & handline fleet and drifting longline fleet). *Status quo* levels of fishing effort (averaged over the last three years) of all fishing fleets included in the model were assumed.

- ***Implementation of fishing effort reductions - FE strategy***

  Forecasts resulting from effort reductions of the bottom fishing fleets from *status quo*, proportional to the effort lost within each network of closed areas. Simulations were performed without the implementation of no-take areas.

- ***Implementation of marine protected areas accompanied by fishing effort reductions - MPA + FE strategy***

  Forecasts resulting from the implementation of the twenty-four systematic conservation planning scenarios as no-take areas for bottom fishing gears and fishing effort reduction for bottom fishing gears. The fishing effort reduction from *status quo* levels was proportional to the effort lost within the networks of closed areas.

- ***Business As Usual - BAU***

  A Business As Usual (BAU) model was used as reference to evaluate the performance of the multiple strategies. The model did not include spatial management strategies and assumed *status quo* fishing effort levels of all fishing gears. The model included current regulations that spatially restrict the operation of pelagic fleets around the islands and foreign fleets within 100nm. The current regional network of the protected areas declared in the Azores Marine Park was disregarded.

Future projections assumed no environmental variability driving the abundance of primary producers in all scenarios (environmental conditions were assumed to be an average of the last three years). The Ecospace model does not exclude the 6nm buffer beyond island shores, assumed in the “data-rich” spatial planning area. For that reason, the proportion of fishing effort within network scenarios are slightly different from those calculated with Marxan’s solutions. The ecosystem model assumes the bottom longliners and handliners as a single fleet, due to the difficulty of differentiating total catches among the fleets. Therefore, the 6nm regulation (Portaria 50/2012) were not implemented in this approach.

Spatial resampling techniques were used to convert the resolution of Marxan optimized solutions (5km in latitude and longitude) into Ecospace resolution (10km in latitude and longitude). Hence, each cell of the Ecospace grid contained 4 PUs of the prioritization grid. Due to the differences in the spatial resolution between the approaches, a threshold was applied to guarantee that Ecospace cells covered at least 50% of the Marxan solution. The threshold was set so the aggregation did not substantially increase the size of the network, while small reserves were not excluded from the simulation.

The overarching goal of the ecosystem-based assessment was to assess which scenarios maximize the achievement of ecosystem-based management goals and objectives (conservation and fisheries), embedded in the overarching mission of sustainable use of natural resources. We also aimed at assessing the performance of the systematic conservation planning scenarios achieving quantitative targets of "reserve effects" described above and ultimately understand to which extent network attributes (i.e., size, design) influence the magnitude of such effects.

Three metrics were used to investigate which scenarios maximize the achievement of ecosystem-based management goals and objectives, and achieving quantitative targets of "reserve effect": a) the ratio of change on biomass and catch of deep-sea and shallow-water fish between, before the management implementation (2019; year 0) and the end of the simulation (2040; year 20); b) the same ratio of change on suitable biomass but in response to MPA network attributes, such as, the extent (size), design (shape), and location (placement and spacing) and c) the absolute suitable biomass of deep-sea and shallow-water fish, projected within and outside the network of priority areas, before the management implementation and by the end of the simulation. The term suitable refers to the biomass present on habitats that represent more than the 95th percentile of foraging capacity. The scenario that used 15% target of the spatial planning area to be included in the prioritization solutions was used to evaluate the influence of the prioritization approach in the overall temporal biomass and fisheries projections and in the spatial distribution of fishing effort and biomass of benthic species.

Nonetheless, ecosystem-wide effects of marine reserves do also encompass spatial organization of trophic cascades, as the biomass of top-predator builds-in inside the protected area (Walters et al., 2000). Consequently, the abundance of their prey might depress within the reserve, possibly resulting in a biomass decrease at lower trophic levels (Cheng et al., 2019). Trophic spectrum is a graphical representation of the biomass distribution of the ecosystem across trophic levels, thus providing a simplified view of the ecosystem structure (Gascuel et al., 2005). Changes in the trophic spectrum can underpin impacts of fishing and/or predation down the food-web. The analyses of the trophic spectrum was used to project the effect of the MPA networks in the ecosystem structure in general and in high trophic level groups in particular. The goal of the analysis was to evaluate whether local spatial organization of trophic cascades could be expected within marine reserves. The trophic spectrum was measured within the MPA networks relative to the BAU to perceive the biomass changes by trophic level. The analysis focused on the systematic conservation planning scenarios targeting 10%, 15%, 30% and 50% of planning area using the high clumping design, the area-based cost function, and under the MPA + FE strategy. These scenarios were selected because they represent the most conservative management strategies.

6. Systematic conservation planning scenarios outputs

6.1 Spatial planning area target: 10%

Goal: Restoring fish stocks of commercially important deep-sea benthic species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores EEZ.

Planning area: "Data-rich" & "Data-poor abyssal" combined with 3 subregions for network representativity and replication ("data-rich West", "data-rich MAR" and "data-rich East", and "data-poor abyssal West", "data-poor abyssal Northeast" and "data-poor abyssal Northwest").

Features considered:

- Important resources; commercially important deep-sea fish, vulnerable deep-sea sharks and rays, inferred habitat-structuring CWC, inferred Vulnerable Marine Ecosystems, observed habitat-structuring CWC;
- Important areas, VME; 10 hydrothermal vent (Saldanha, Famous, Lucky Strike, Menez Hom and South Lucky Strike, Menez Gwen and Bubbylon, Luso, Don Joao de Castro, and South Kurchatov);
- Important areas, VME; 3 portion of the MAR (Western ridge, Ridge east of Gigante, Cavalo), nine seamount-like features (Oscar, Gigante, Cavala, Beta, Voador, Condor, south-east of Pico Island, Don João de Castro, and Formigas);
- Important areas, essential fish habitats; 2 seamounts (Sedlo and Hard Rock Café seamounts)
- Important areas, shallow and very deep seamounts; 11 shallow water seamounts (Açor 160m depth, Condor 190m depth, Don João de Castro 20m depth, Formigas 0m depth, Gigante 160m depth, 127 160m depth, Grande Norte 120m depth, Mar da Prata Norte 170m depth and Mar da Prata Sul 260m depth, Princesa Alice 40m depth, and Voador 230m depth) and two deep-seamounts in the "data-rich" area (both probably named São Mateus de fora; deeper than approx. 1400m depth).
- Important areas, near-natural areas; 1 seamount (Diogo Teive);
- Representativity; Geomorphic Management Units (GMUs).

Constraint on existing marine reserves: not implemented.

Spatial planning area target: 10%.

Configurations of priority areas: high, medium, and low clumping.

Cost models: area-based cost and fisheries-based cost.

Summary of the outputs: The 10% target scenarios, selected an average of 151 priority areas (71-224), covering about 4.1% of the whole spatial planning area, 6.6% of the "data rich" and 2.8% of the "data-poor abyssal" areas. The 10% targets were not achieved in the prioritization solutions because the information was considered to be insufficient to implement a data-driven approach in the "data-poor abyssal" area and in the abyssal plain (flat areas) of the "data-rich area" (Section 5.4.2). In average, 54.5% of the network is located in the "data rich" while 45.5% is on the "data-poor abyssal" areas, and 4.3% of the selected network is already protected with existing regulations (Table 24). The resulting network of priority areas is spread throughout the whole EEZ (i.e. spatial planning area), but with a poor coverage in the NE and NW portions of the "data-poor abyssal" area (Figure 44; Figure 45). It should be noted that the proportion of the network area that is isolated increased significantly comparing the low and medium clumping design (0.4%) with the high clumping design (16%; Table 24) The area-based cost 10% scenarios obtained higher representativity for the shallow water depths (0-600m, Island Shelf Unit, and shallow seamounts) while the fisheries-based cost scenarios obtained slightly higher representativity for some deep waters features (deep seamounts) (Table 25). The area-based cost scenarios included more fish, sharks and rays and cold-water corals suitable habitat in the solutions than the fisheries-based cost solution (21.4% and 17.5%, respectively; Table 26). Not surprisingly, the fisheries-based cost scenarios reduced the average overlap with existing fishing footprint from 19.6% (area-based cost) to 14.2% and the overlap with existing fishing effort from 24.9% to 20.6% (Figure 46). The “species richness” map highlights that most hotspots areas are being capture in both the area-based and fisheries-based cost (Figure 47).

6.1.1 *Scenario 10% of the spatial planning area: prioritization solutions including the locked-in areas*

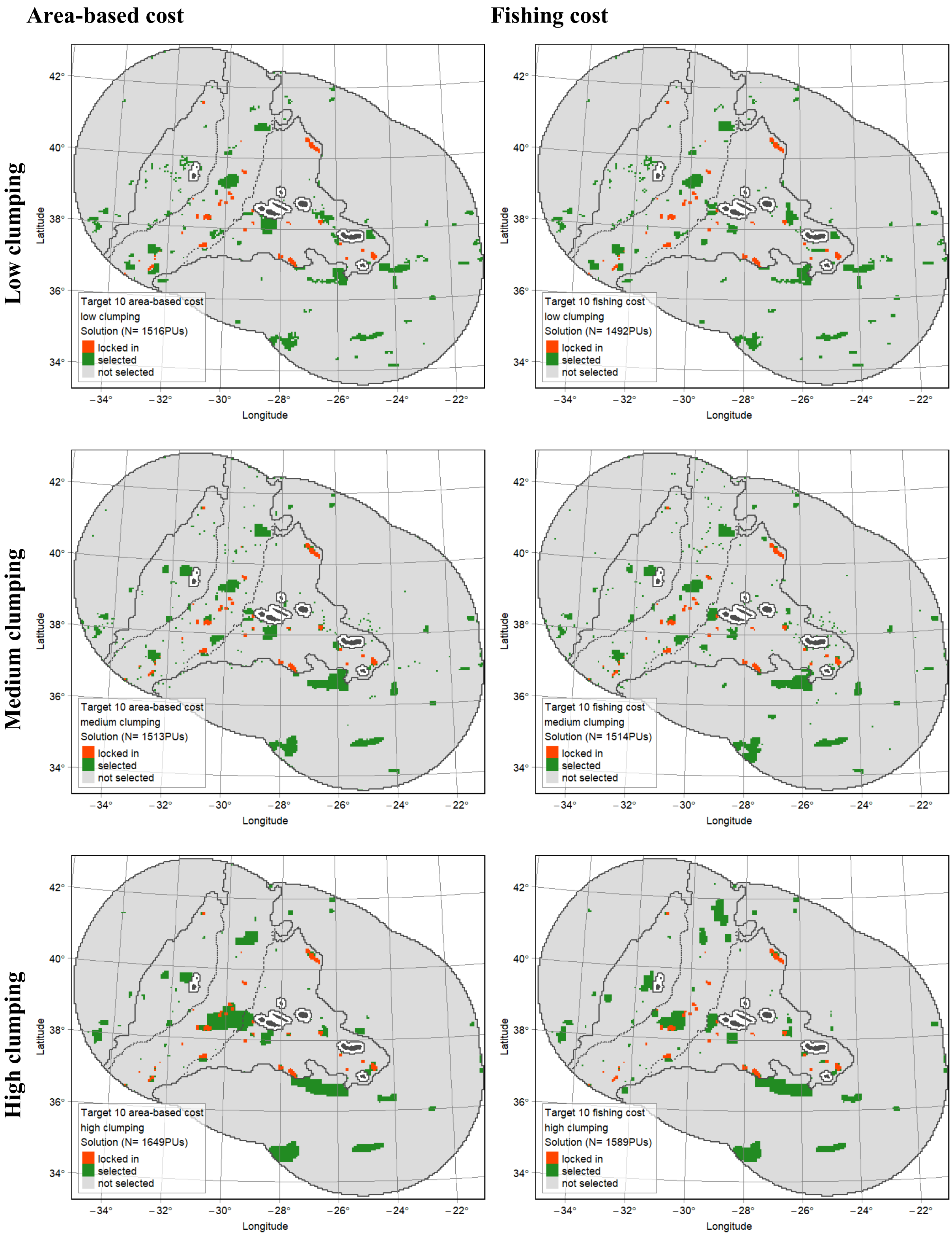


Figure 44. Prioritization solutions including the locked-in areas for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 10% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.1.2 Scenario 10% of the spatial planning area: prioritization solutions to 1) "protect" areas outside the present bottom fisheries footprint, and 2) "restore" areas in the present bottom fisheries footprint.

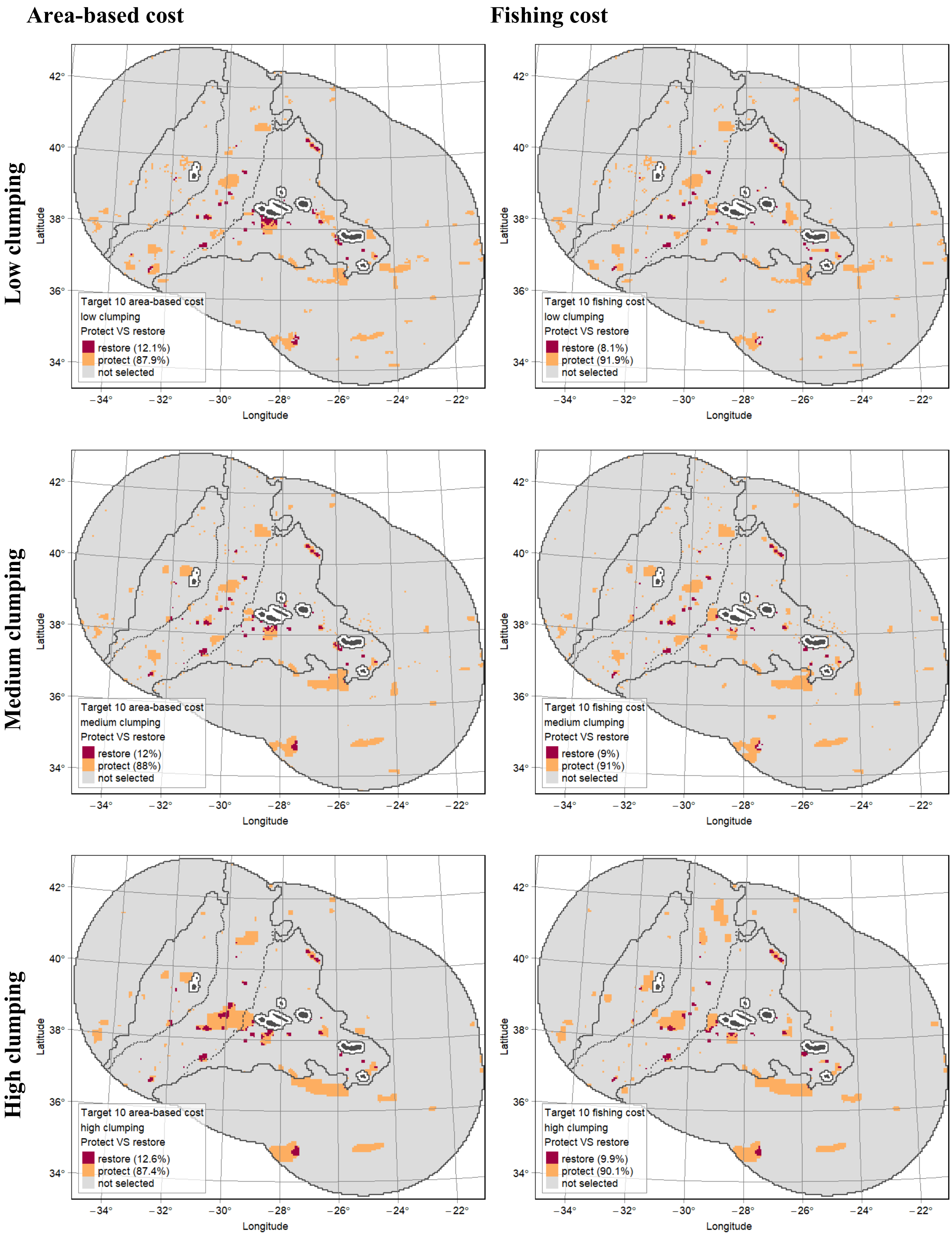


Figure 45. Prioritization solutions to 1) "protect" areas outside and 2) "restore" areas inside the present bottom fisheries footprint for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 10% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.1.3 *Scenario 10% of the spatial planning area: Fishing effort in the prioritization solutions.*

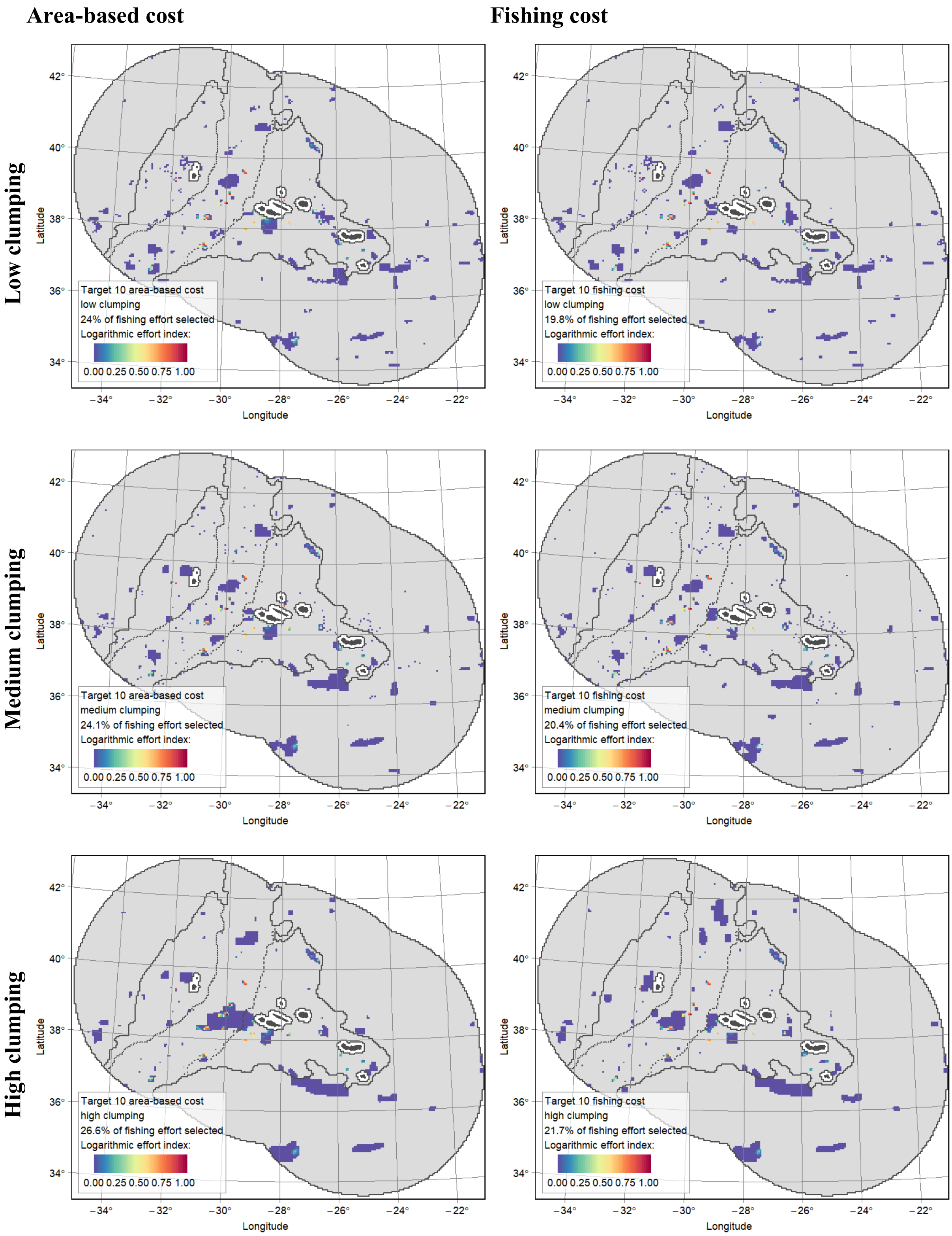


Figure 46. Fishing effort in the prioritization solutions for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 10% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.1.4 Scenario 10% of the spatial planning area: A "species richness" map exhibiting the number of features occurring in the prioritization solutions. The areas with a 0 value contained only GMUs.

Area-based cost **Fishing cost**

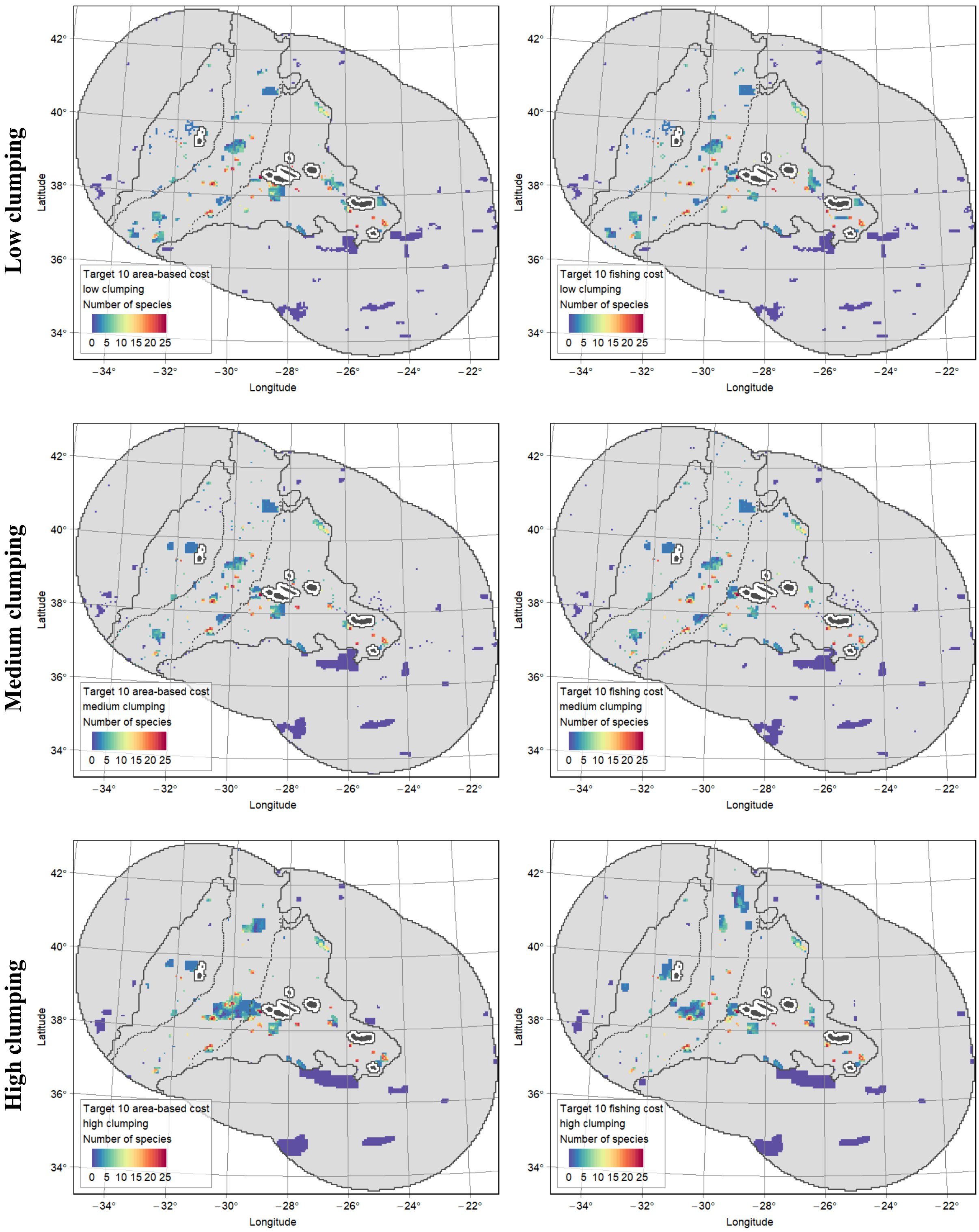


Figure 47. Number of features occurring in the prioritization solutions for the overarching goal of restoring deep-sea fish stocks while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 10% target, 3 different configurations (high, medium and low clumping), and fisheries-based cost. The areas with a 0 value contained only GMUs.

6.2 Spatial planning area target: 15%

Goal: Restoring fish stocks of commercially important deep-sea benthic species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores EEZ.

Planning area: "Data-rich" & "Data-poor abyssal" combined with 3 subregions for network representativity and replication ("data-rich West", "data-rich MAR" and "data-rich East", and "data-poor abyssal West", "data-poor abyssal Northeast" and "data-poor abyssal Northwest").

Features considered:

- Important resources; commercially important deep-sea fish, vulnerable deep-sea sharks and rays, inferred habitat-structuring CWC, inferred Vulnerable Marine Ecosystems, observed habitat-structuring CWC;
- Important areas, VME; 10 hydrothermal vent (Saldanha, Famous, Lucky Strike, Menez Hom and South Lucky Strike, Menez Gwen and Bubbylon, Luso, Don Joao de Castro, and South Kurchatov);
- Important areas, VME; 3 portion of the MAR (Western ridge, Ridge east of Gigante, Cavalo), nine seamount-like features (Oscar, Gigante, Cavala, Beta, Voador, Condor, south-east of Pico Island, Don João de Castro, and Formigas);
- Important areas, essential fish habitats; 2 seamounts (Sedlo and Hard Rock Café seamounts)
- Important areas, shallow and very deep seamounts; 11 shallow water seamounts (Açor 160m depth, Condor 190m depth, Don João de Castro 20m depth, Formigas 0m depth, Gigante 160m depth, 127 160m depth, Grande Norte 120m depth, Mar da Prata Norte 170m depth and Mar da Prata Sul 260m depth, Princesa Alice 40m depth, and Voador 230m depth) and two deep-seamounts in the "data-rich" area (both probably named São Mateus de fora; deeper than approx. 1400m depth).
- Important areas, near-natural areas; 1 seamount (Diogo Teive);
- Representativity; Geomorphic Management Units (GMU).

Constraint on existing marine reserves: not implemented.

Spatial planning area target: 15%.

Configurations of priority areas: high, medium, and low clumping.

Cost models: area-based cost and fisheries-based cost

Summary of the outputs: The 15% target scenarios, selected an average of 16294 priority areas (76-260), covering about 5.6% of the whole spatial planning area, 9.4% of the "data rich" and 3.6% of the "data-poor abyssal" areas. The 15% targets were not achieved in the prioritization solutions because the information was considered to be insufficient to implement a data-driven approach in the "data-poor abyssal" area and in the abyssal plain (flat areas) of the "data-rich area" (Section 5.4.2). In average, 57% of the network is located in the "data rich" while 43% is on the "data-poor abyssal" areas, and 3.3% of the selected network is already protected with existing regulations (Table 24). The resulting network of priority areas resulted of an expansion of the 10% scenarios, spreading throughout the whole EEZ (i.e. spatial planning area), but with a slightly better coverage in the North portion of the Mid-Atlantic Ridge and in the NW portions of the "data-poor abyssal" area in all clumping scenarios (Figure 48, Figure 49). The proportion of the network area that is isolated increased in the high clumping design (8%) but was much lower than in the 10% scenario (Table 24). The fisheries-based cost and low clumping scenario was able to reduce significantly the overlap with existing fishing footprint to approx. 13% (Figure 49, Figure 50, Table 24). The area-based cost 15% scenarios obtained higher representativity for most water depths and for shallow seamounts while the fisheries-based cost scenarios obtained slightly higher representativity for deep seamounts (Table 25). Not surprisingly, area-based cost scenarios included more suitable habitat of various species in the solutions than the fisheries-based cost solution (22.0% and 19.9%, respectively; Table 26). The fisheries-based cost scenarios reduced the average overlap with existing fishing footprint from 23.1% (area-based cost) to 16.6% and the overlap with existing fishing effort from 28.6% to 12.3% (Figure 50). The “species richness” map highlights that most hotspots areas are being capture in both the area-based and fisheries-based cost (Figure 51).

6.2.1 *Scenario 15% of the spatial planning area: prioritization solutions including the locked-in areas*

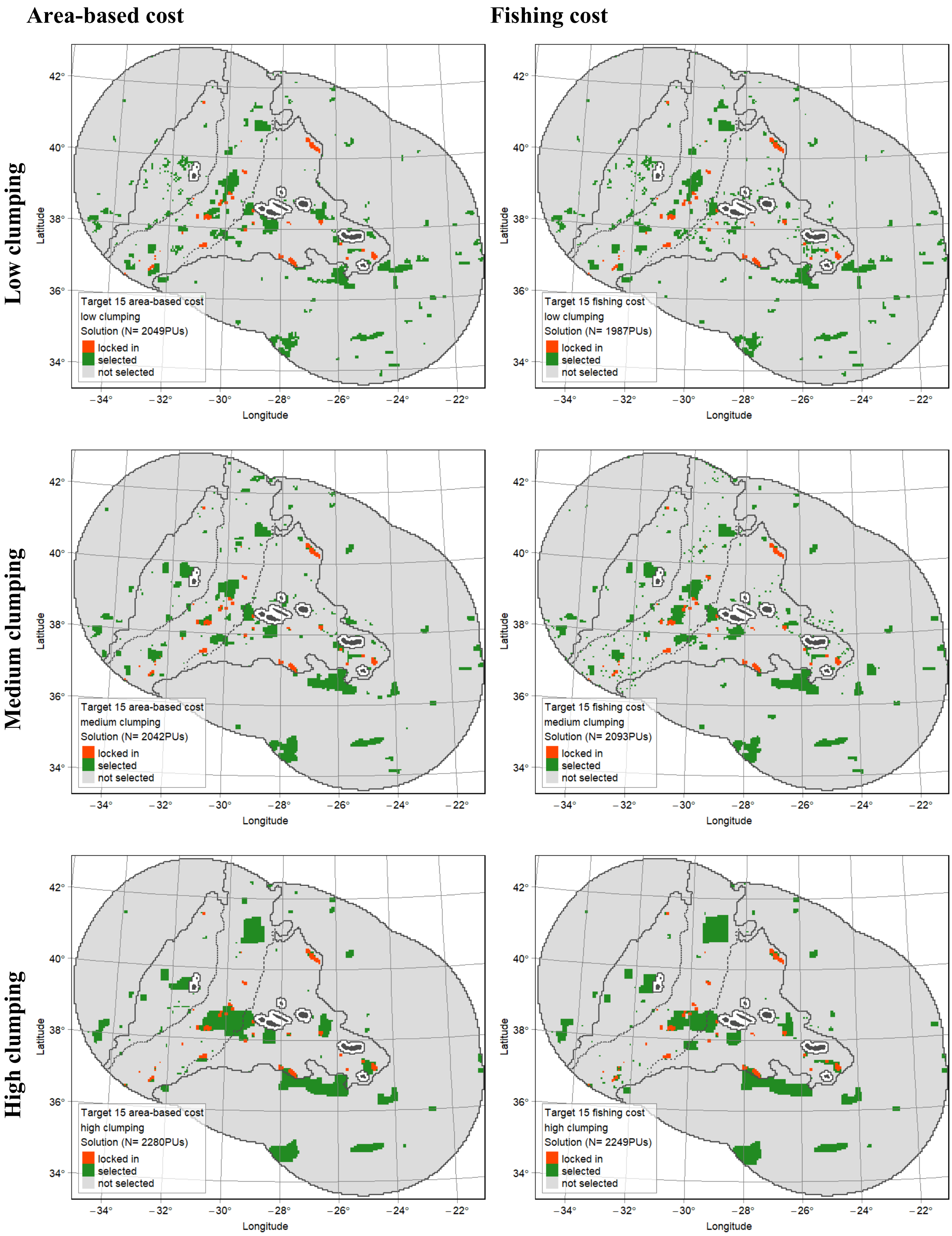


Figure 48. Prioritization solutions including the locked-in areas for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 15% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.2.2 *Scenario 15% of the spatial planning area: prioritization solutions to 1) "protect" areas outside the present bottom fisheries footprint, and 2) "restore" areas in the present bottom fisheries footprint.*

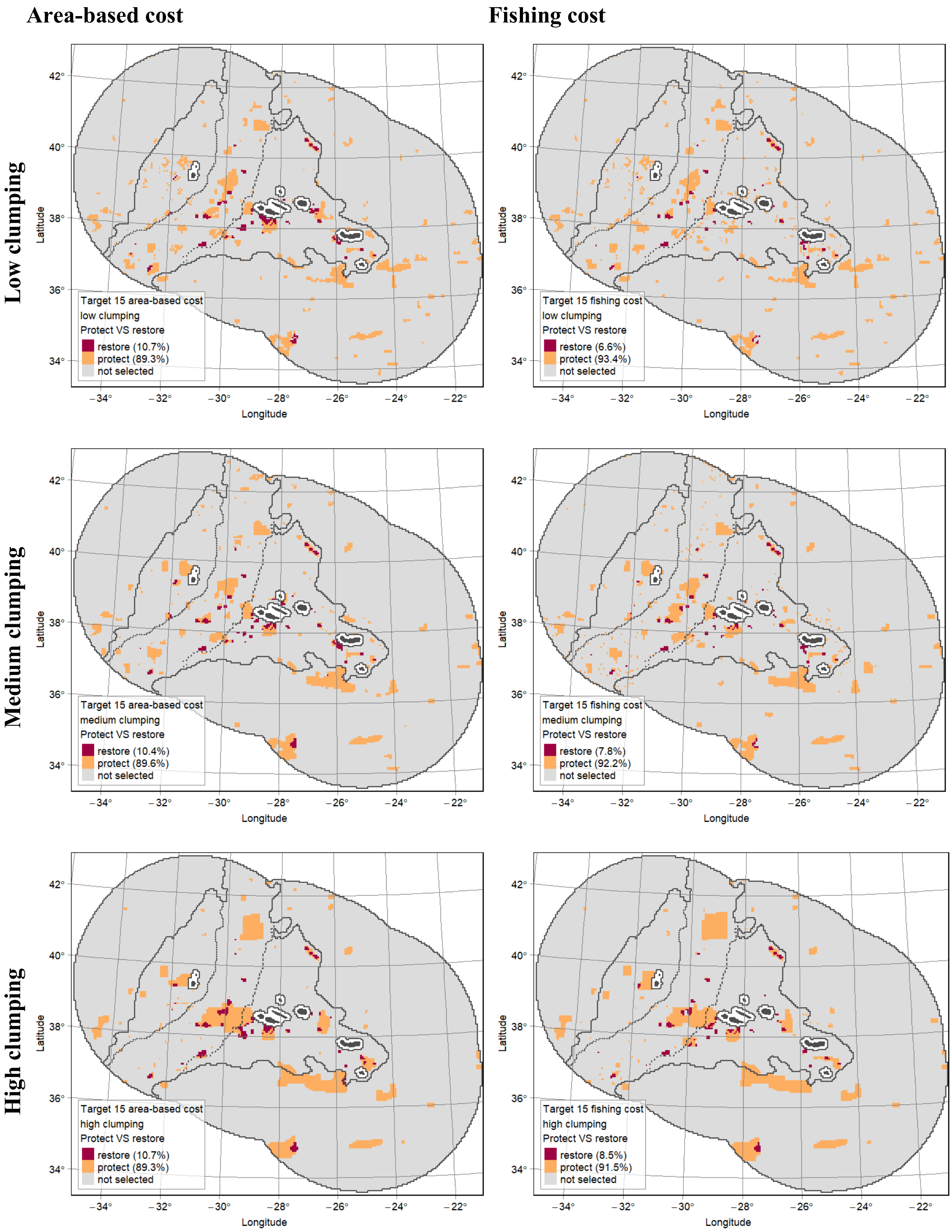


Figure 49. Prioritization solutions to 1) "protect" areas outside and 2) "restore" areas inside the present bottom fisheries footprint for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 15% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.2.3 *Scenario 15% of the spatial planning area: Fishing effort in the prioritization solutions.*

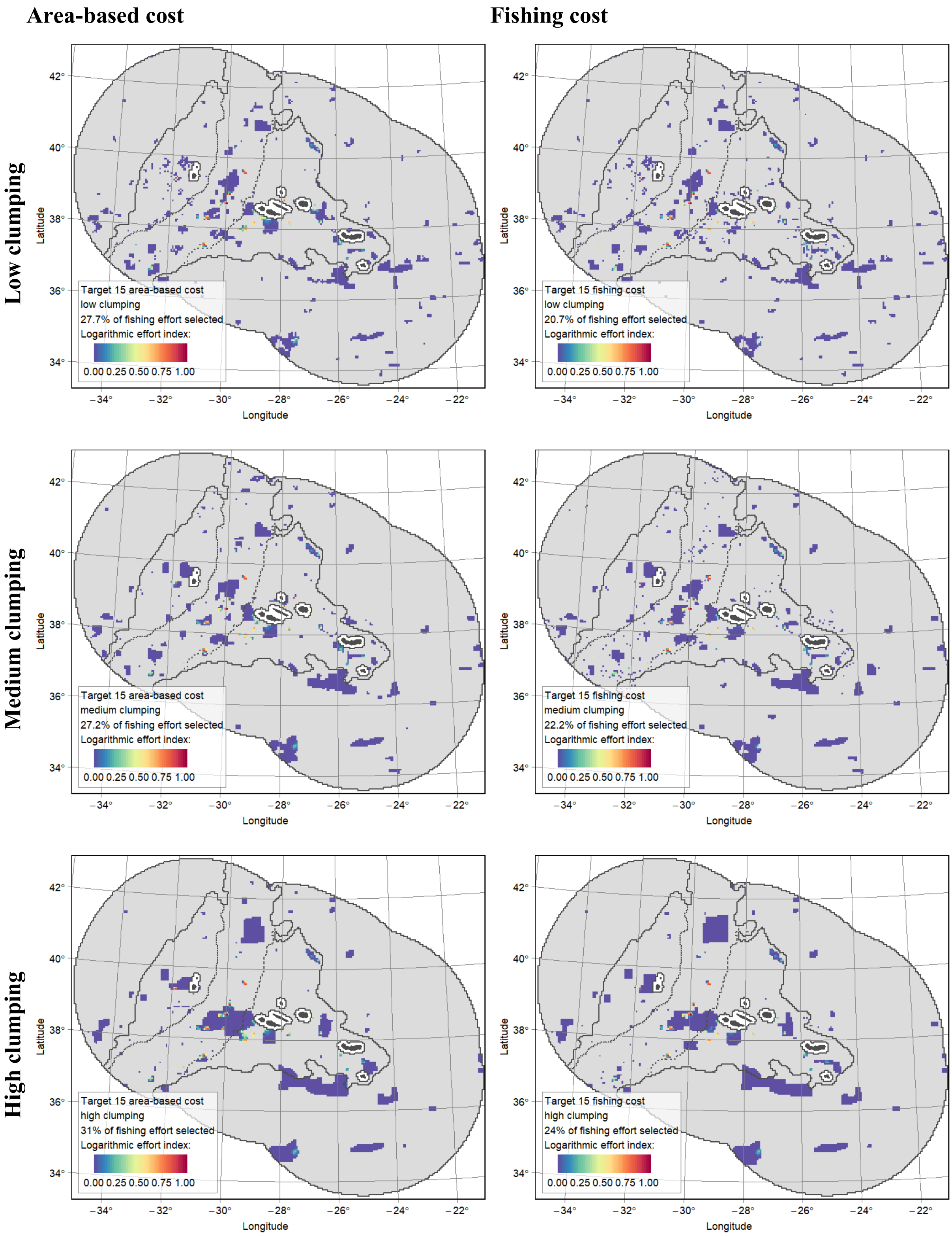


Figure 50. Fishing effort in the prioritization solutions for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 15% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.2.4 *Scenario 15% of the spatial planning area: A "species richness" map exhibiting the number of features occurring in the prioritization solutions. The areas with a 0 value contained only GMUs.*

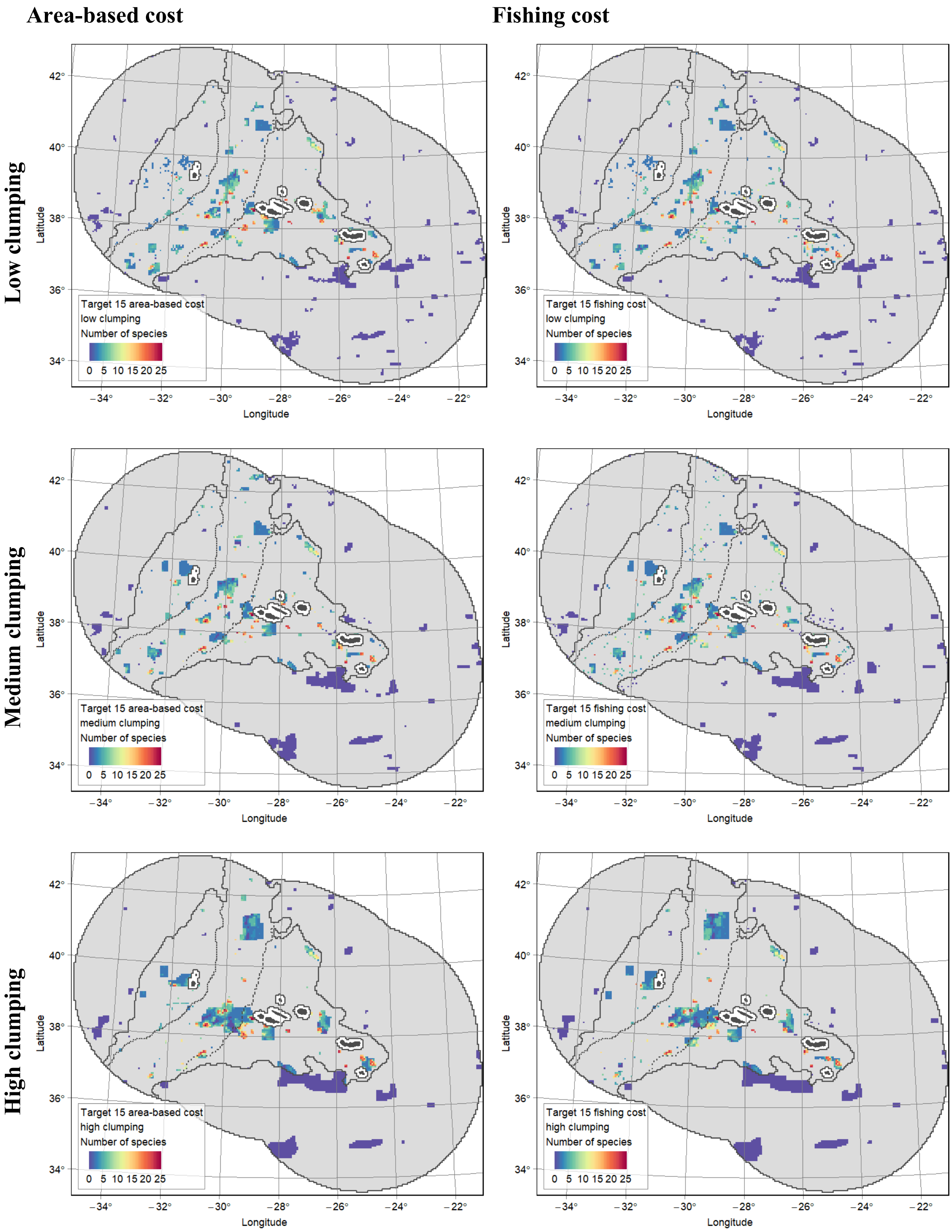


Figure 51. Number of features occurring in the prioritization solutions for the overarching goal of restoring deep-sea fish stocks while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 15% target, 3 different configurations (high, medium and low clumping), and fisheries-based cost. The areas with a 0 value contained only GMUs.

6.3 Spatial planning area target: 30%

Goal: Restoring fish stocks of commercially important deep-sea benthic species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores EEZ.

Planning area: "Data-rich" & "Data-poor abyssal" combined with 3 subregions for network representativity and replication ("data-rich West", "data-rich MAR" and "data-rich East", and "data-poor abyssal West", "data-poor abyssal Northeast" and "data-poor abyssal Northwest").

Features considered:

- Important resources; commercially important deep-sea fish, vulnerable deep-sea sharks and rays, inferred habitat-structuring CWC, inferred Vulnerable Marine Ecosystems, observed habitat-structuring CWC;
- Important areas, VME; 10 hydrothermal vent (Saldanha, Famous, Lucky Strike, Menez Hom and South Lucky Strike, Menez Gwen and Bubbylon, Luso, Don Joao de Castro, and South Kurchatov);
- Important areas, VME; 3 portion of the MAR (Western ridge, Ridge east of Gigante, Cavalo), nine seamount-like features (Oscar, Gigante, Cavala, Beta, Voador, Condor, south-east of Pico Island, Don João de Castro, and Formigas);
- Important areas, essential fish habitats; 2 seamounts (Sedlo and Hard Rock Café seamounts)
- Important areas, shallow and very deep seamounts; 11 shallow water seamounts (Açor 160m depth, Condor 190m depth, Don João de Castro 20m depth, Formigas 0m depth, Gigante 160m depth, 127 160m depth, Grande Norte 120m depth, Mar da Prata Norte 170m depth and Mar da Prata Sul 260m depth, Princesa Alice 40m depth, and Voador 230m depth) and two deep-seamounts in the "data-rich" area (both probably named São Mateus de fora; deeper than approx. 1400m depth).
- Important areas, near-natural areas; 1 seamount (Diogo Teive);
- Representativity; Geomorphic Management Units (GMU).

Constraint on existing marine reserves: not implemented.

Spatial planning area target: 30%.

Configurations of priority areas: high, medium, and low clumping.

Cost models: area-based cost and fisheries-based cost

Summary of the outputs: The 30% target scenarios, selected an average of 171 priority areas (64-281), covering about 6.3% of the whole spatial planning area, 10.9% of the "data rich" and 3.9% of the "data-poor abyssal" areas. As in the other scenarios, the 30% targets were not achieved in the prioritization solutions because the information was considered to be insufficient to implement a data-driven approach in the "data-poor abyssal" area and in the abyssal plain (flat areas) of the "data-rich area" (Section 5.4.2). In average, 59% of the network is located in the "data rich" while 41% is on the "data-poor abyssal" areas, and 3.2% of the selected network is already protected with existing regulations (Table 24). The resulting network of priority areas it's really an expansion of the 15% scenario with a slightly better representativity in the south and north MAR and higher selected areas in the western portion of the "data-rich" area (Figure 52, Figure 53). In this scenario, the proportion of the network area that is isolated is only slightly higher in the high clumping design (4.5%) when compared to the low and medium clumping designs (1.7%; Table 24). Similarly to the other spatial planning area targets, the area-based cost 30% scenarios obtained higher representativity for most water depths and for shallow seamounts while the fisheries-based cost scenarios obtained slightly higher representativity for deep seamounts (Table 25). The area-based cost scenarios still included more suitable habitat of most conservation features in the solutions than the fisheries-based cost solution (Table 26). Finally, the fisheries-based cost scenarios reduced the average overlap with existing fishing footprint from 33.6% (area-based cost) to 22.0% and the overlap with existing fishing effort from 43.6% to 27.8% (Figure 54). The “species richness” map highlights that most hotspots areas are being capture in both the area-based and fisheries-based cost (Figure 55).

6.3.1 Scenario 30% of the spatial planning area: prioritization solutions including the locked-in areas

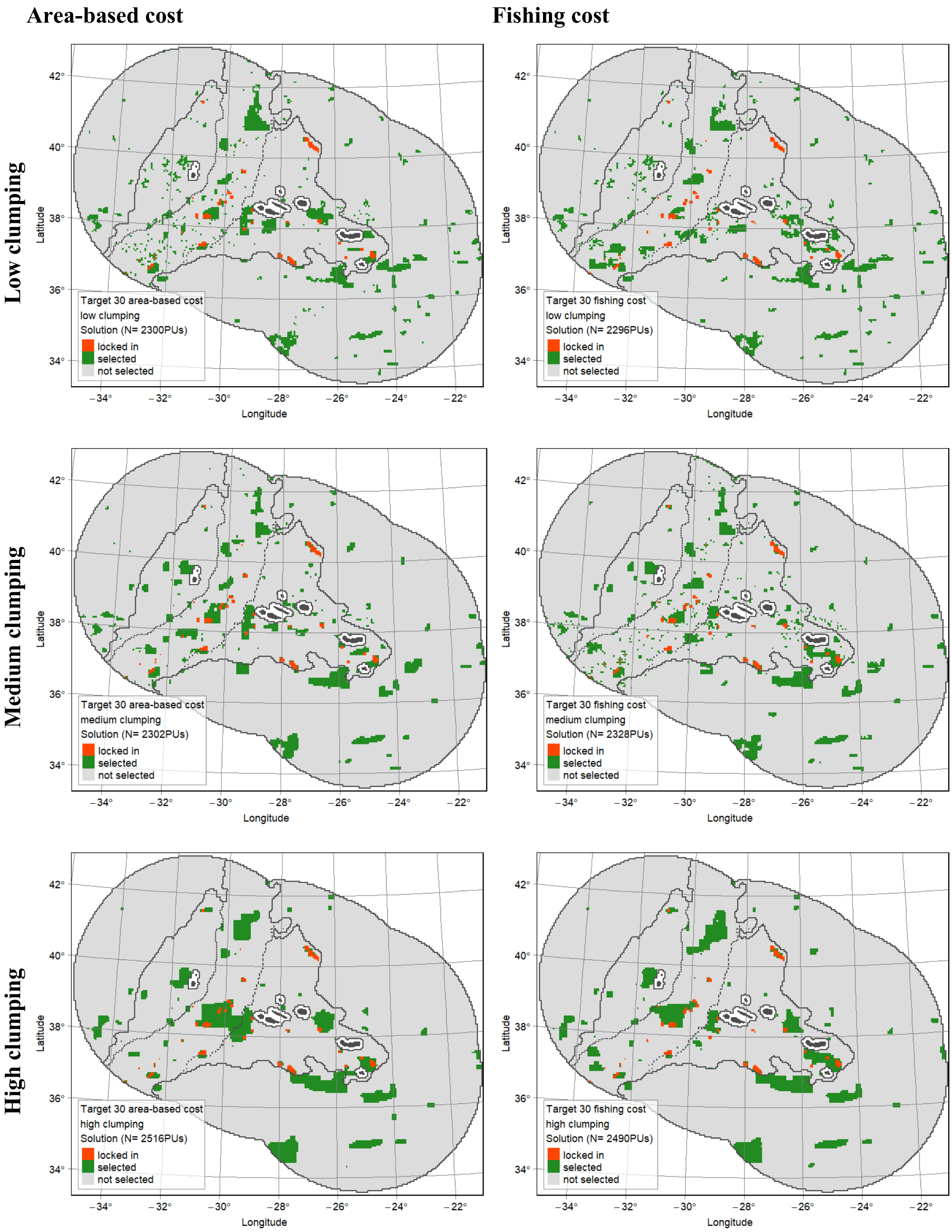


Figure 52. Prioritization solutions including the locked-in areas for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.3.2 *Scenario 30% of the spatial planning area: prioritization solutions to 1) "protect" areas outside the present bottom fisheries footprint, and 2) "restore" areas in the present bottom fisheries footprint.*

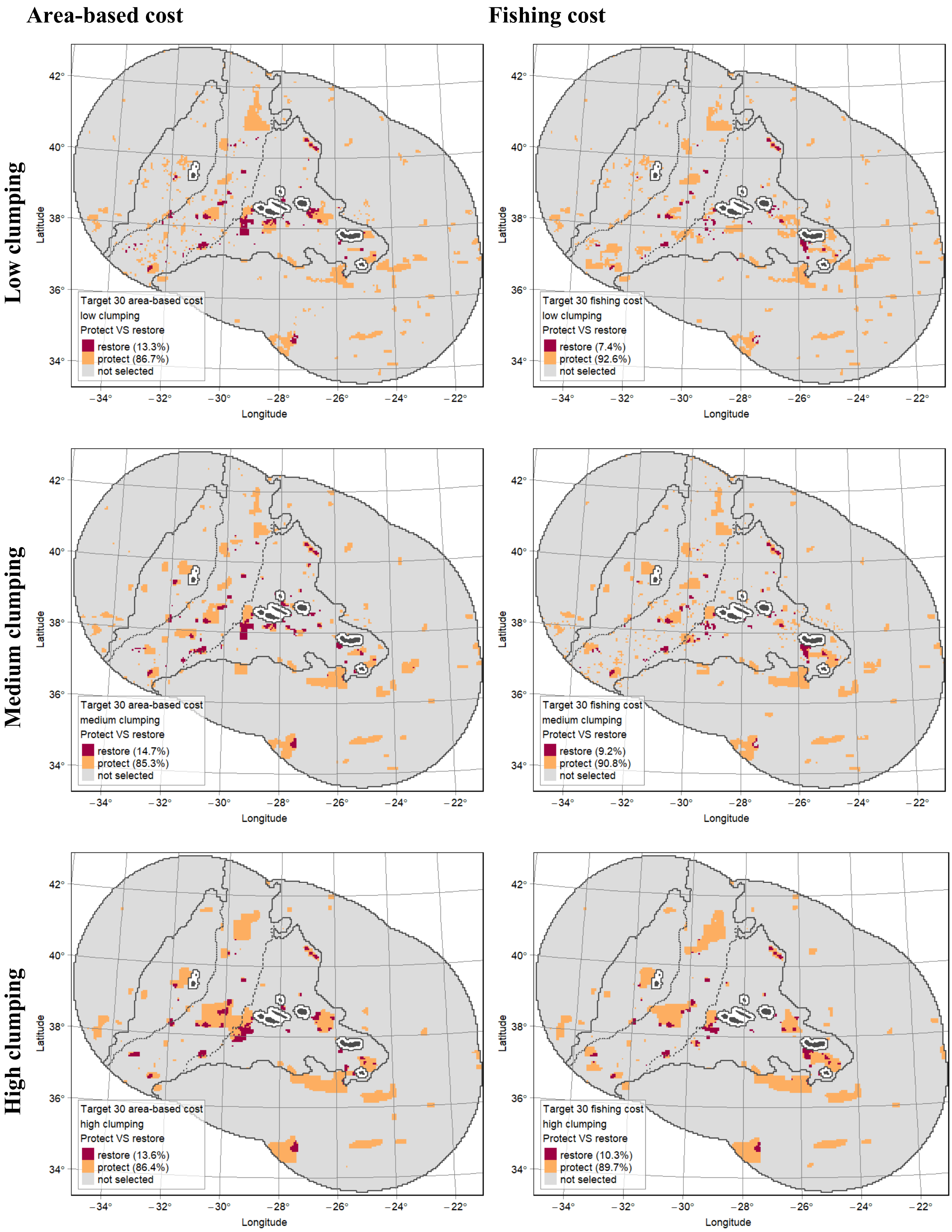


Figure 53. Prioritization solutions to 1) "protect" areas outside and 2) "restore" areas inside the present bottom fisheries footprint for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.3.3 Scenario 30% of the spatial planning area: Fishing effort in the prioritization solutions.

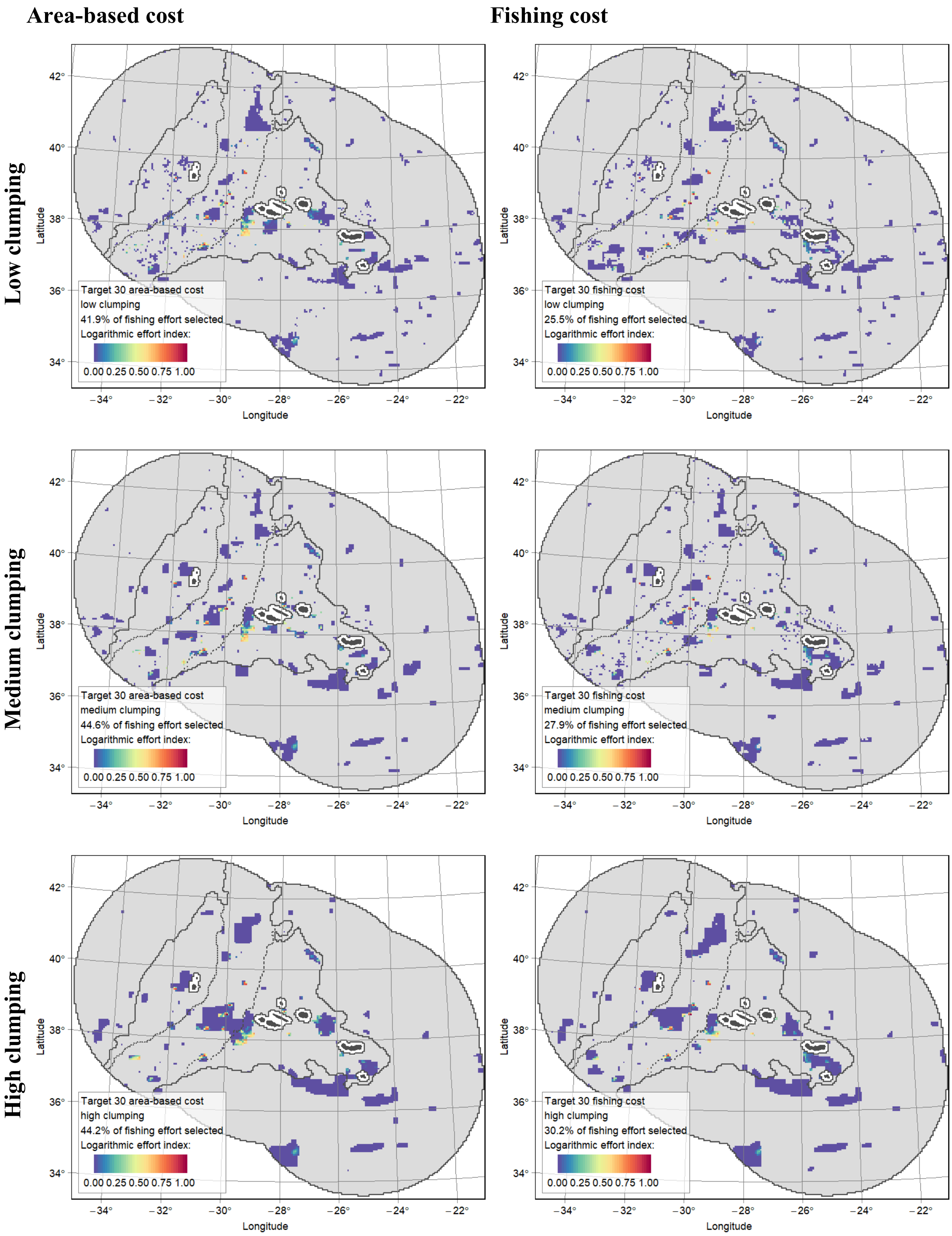


Figure 54. Fishing effort in the prioritization solutions for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.3.4 *Scenario 30% of the spatial planning area: A "species richness" map exhibiting the number of features occurring in the prioritization solutions. The areas with a 0 value contained only GMUs.*

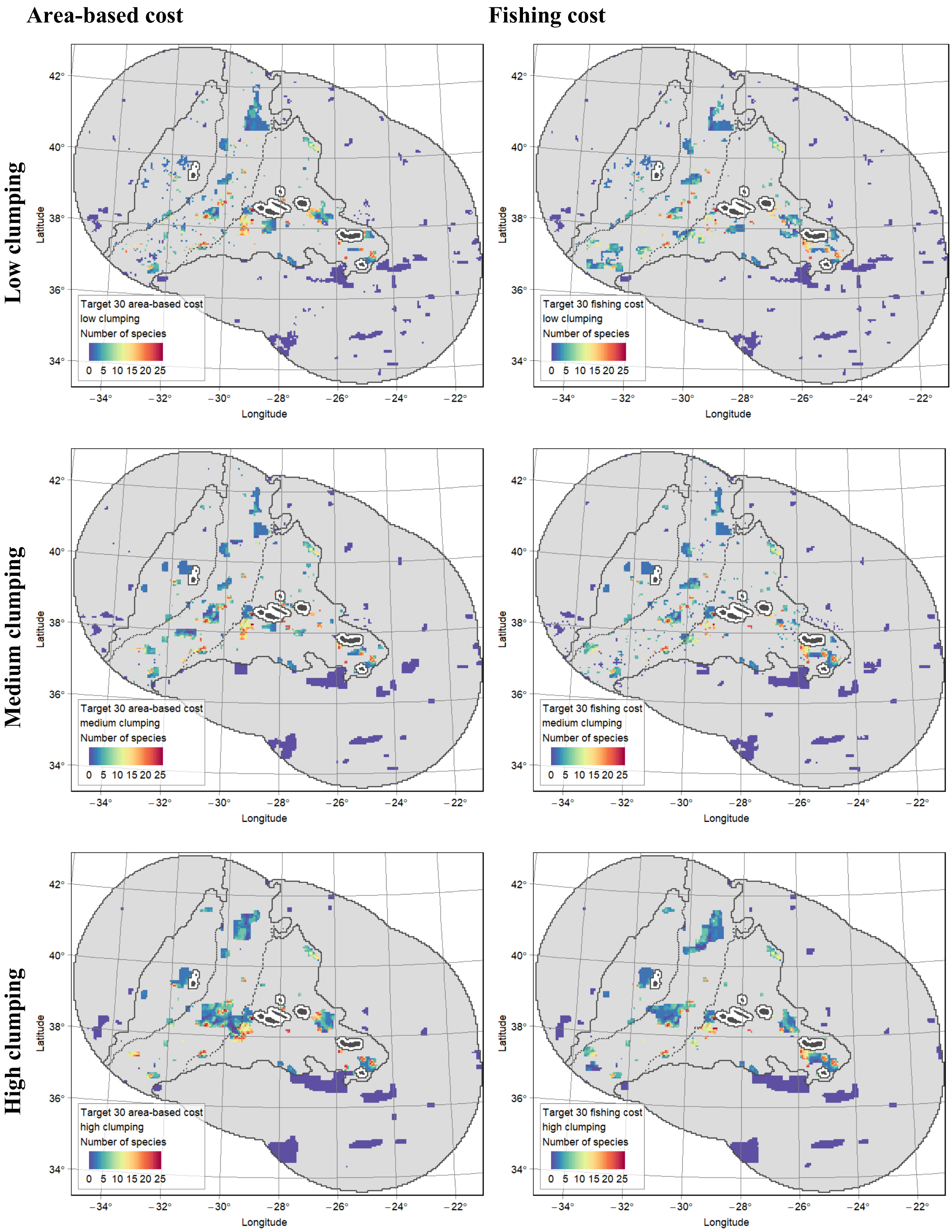


Figure 55. Number of features occurring in the prioritization solutions for the overarching goal of restoring deep-sea fish stocks while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 30% target, 3 different configurations (high, medium and low clumping), and fisheries-based cost. The areas with a 0 value contained only GMUs.

6.4 Spatial planning area target: 50%

Goal: Restoring fish stocks of commercially important deep-sea benthic species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores EEZ.

Planning area: "Data-rich" & "Data-poor abyssal" combined with 3 subregions for network representativity and replication ("data-rich West", "data-rich MAR" and "data-rich East", and "data-poor abyssal West", "data-poor abyssal Northeast" and "data-poor abyssal Northwest").

Features considered:

- Important resources; commercially important deep-sea fish, vulnerable deep-sea sharks and rays, inferred habitat-structuring CWC, inferred Vulnerable Marine Ecosystems, observed habitat-structuring CWC;
- Important areas, VME; 10 hydrothermal vent (Saldanha, Famous, Lucky Strike, Menez Hom and South Lucky Strike, Menez Gwen and Bubbylon, Luso, Don Joao de Castro, and South Kurchatov);
- Important areas, VME; 3 portion of the MAR (Western ridge, Ridge east of Gigante, Cavalo), nine seamount-like features (Oscar, Gigante, Cavala, Beta, Voador, Condor, south-east of Pico Island, Don João de Castro, and Formigas);
- Important areas, essential fish habitats; 2 seamounts (Sedlo and Hard Rock Café seamounts)
- Important areas, shallow and very deep seamounts; 11 shallow water seamounts (Açor 160m depth, Condor 190m depth, Don João de Castro 20m depth, Formigas 0m depth, Gigante 160m depth, 127 160m depth, Grande Norte 120m depth, Mar da Prata Norte 170m depth and Mar da Prata Sul 260m depth, Princesa Alice 40m depth, and Voador 230m depth) and two deep-seamounts in the "data-rich" area (both probably named São Mateus de fora; deeper than approx. 1400m depth).
- Important areas, near-natural areas; 1 seamount (Diogo Teive);
- Representativity; Geomorphic Management Units (GMU).

Constraint on existing marine reserves: not implemented.

Spatial planning area target: 50%.

Configurations of priority areas: high, medium, and low clumping.

Cost models: area-based cost and fisheries-based cost

Summary of the outputs: The 50% target scenarios, selected an average of 256 priority areas (92-431), covering about 8.9% of the whole spatial planning area, 17.9% of the "data rich" and 4.3% of the "data-poor abyssal" areas. As in the other scenarios, the 50% targets were not achieved in the prioritization solutions because the information was considered to be insufficient to implement a data-driven approach in the "data-poor abyssal" area and in the abyssal plain (flat areas) of the "data-rich area" (Section 5.4.2). In average, 32% of the network is located in the "data rich" while 68% is on the "data-poor abyssal" areas, and 2.4% of the selected network is already protected with existing regulations (Table 24). The resulting network of priority areas resulted of an expansion of the 30% scenarios, with good representativity of the whole planning area (Figure 56, Figure 57). Similarly to the other spatial planning area targets, the area-based cost 50% scenarios obtained higher representativity for most water depths and for shallow seamounts while the fisheries-based cost scenarios obtained slightly higher representativity for deep seamounts (Table 25). The area-based and the fisheries based cost scenarios included similar proportions of the suitable habitat of most features in the solutions (Table 26). Finally, the fisheries-based cost scenarios reduced the average overlap with existing fishing footprint from 48.1% (area-based cost) to 34.1% and the overlap with existing fishing effort from 60.2% to 40.8% (Figure 58). The "species richness" map highlights that most hotspots areas are being capture in both the area-based and fisheries-based cost (Figure 59).

6.4.1 *Scenario 50% of the spatial planning area: prioritization solutions including the locked-in areas*

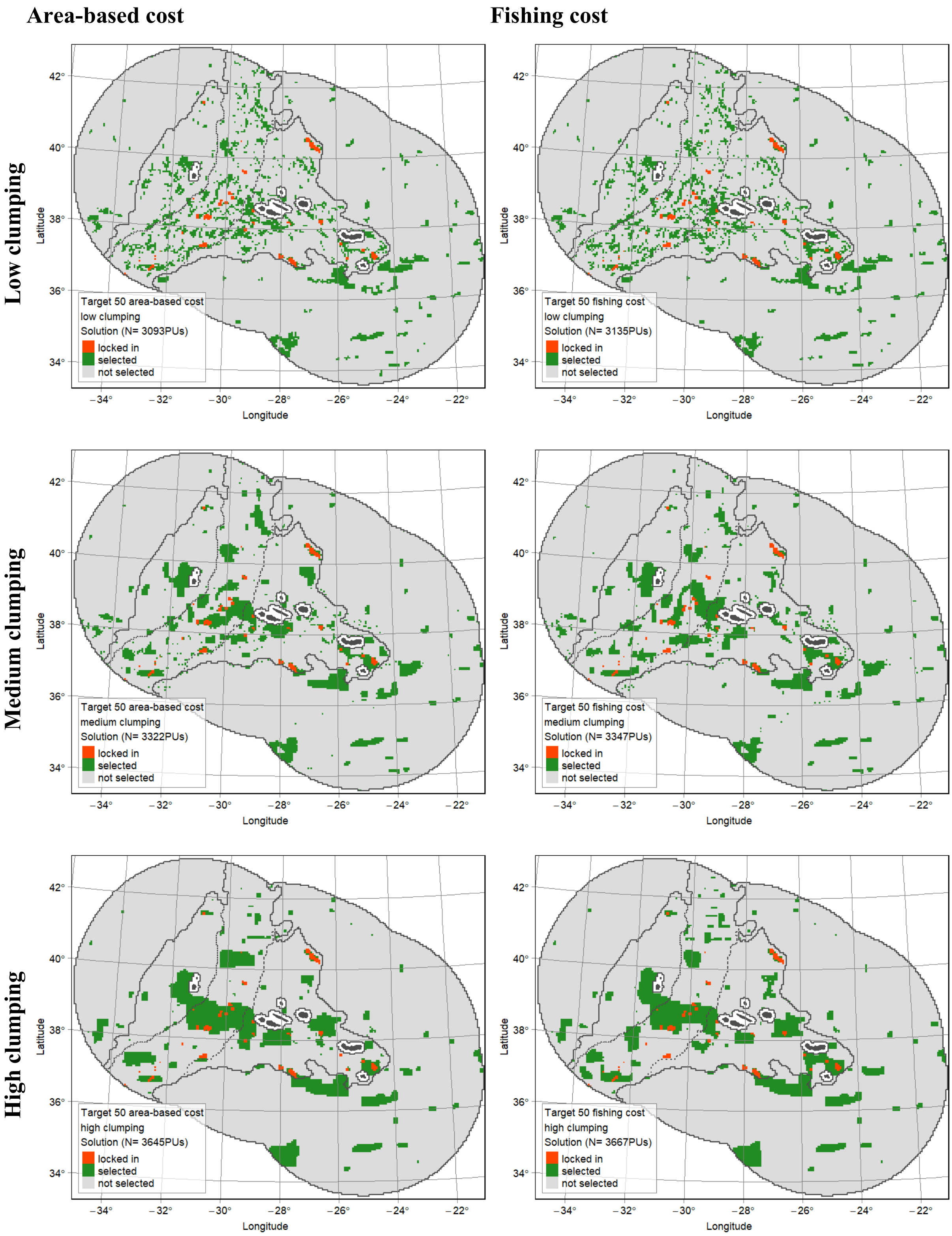


Figure 56. Prioritization solutions including the locked-in areas for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 50% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.4.2 *Scenario 50% of the spatial planning area: prioritization solutions to 1) "protect" areas outside the present bottom fisheries footprint, and 2) "restore" areas in the present bottom fisheries footprint.*

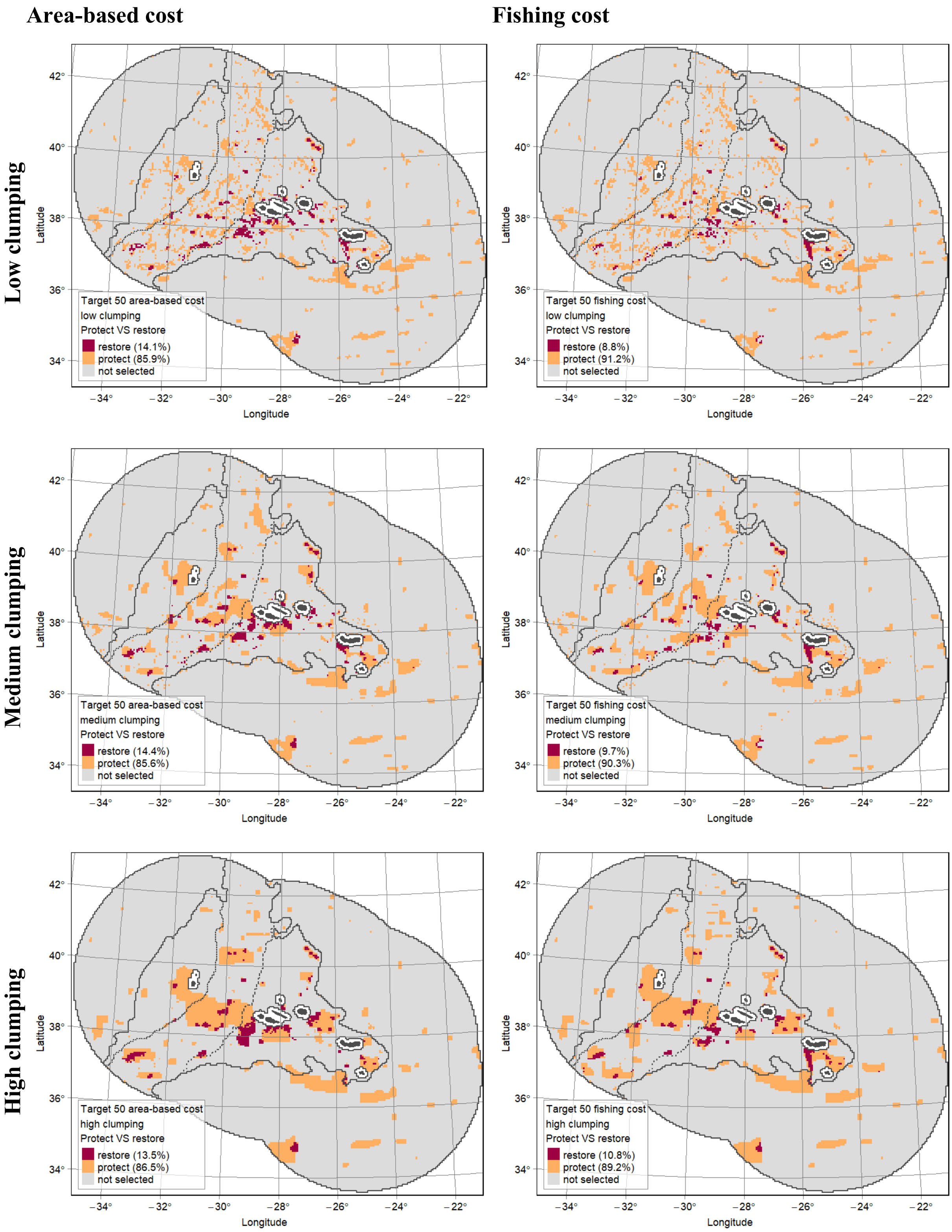


Figure 57. Prioritization solutions to 1) "protect" areas outside and 2) "restore" areas inside the present bottom fisheries footprint for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 50% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.4.3 *Scenario 50% of the spatial planning area: Fishing effort in the prioritization solutions.*

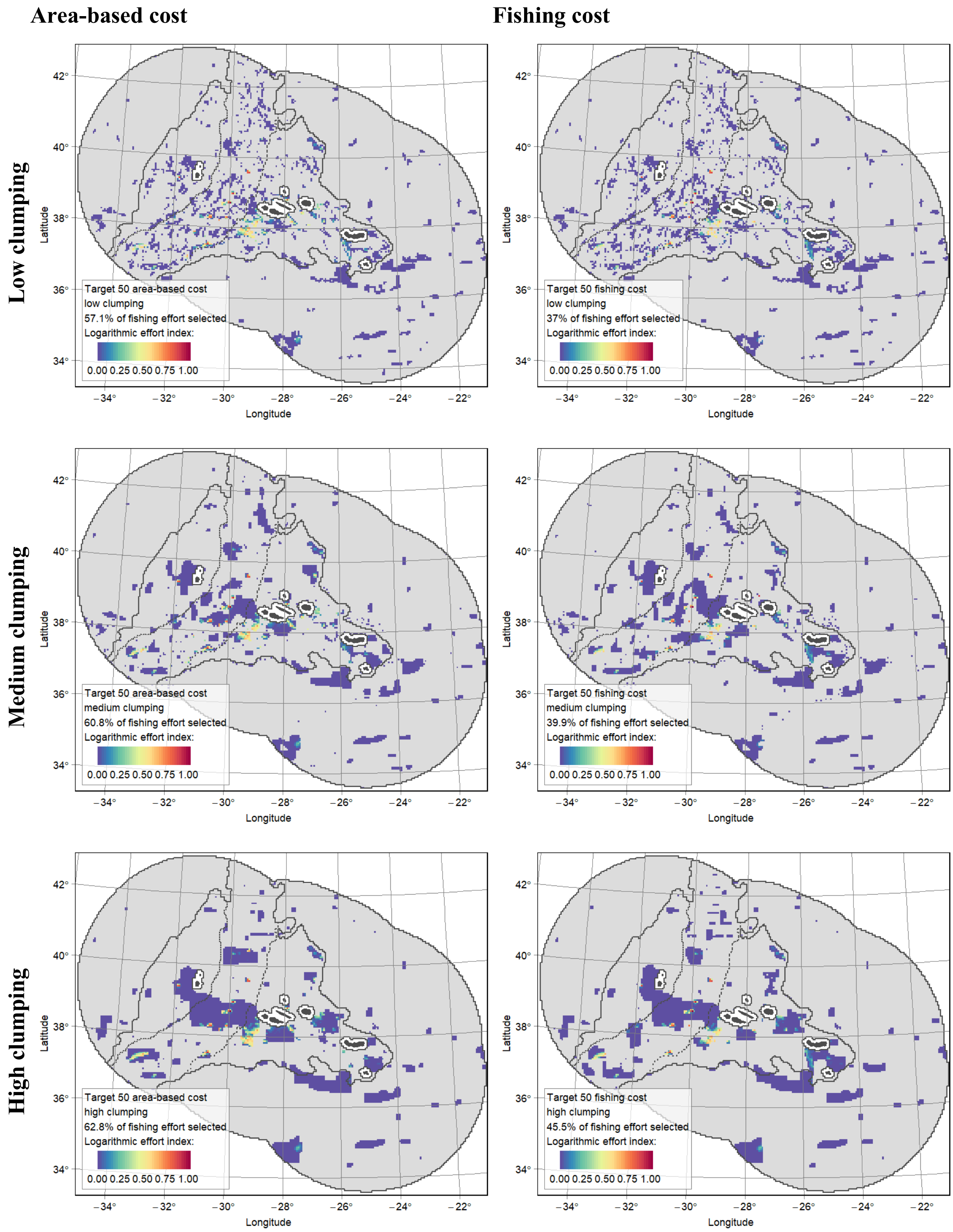


Figure 58. Fishing effort in the prioritization solutions for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 50% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

6.4.4 Scenario 50% of the spatial planning area: A "species richness" map exhibiting the number of features occurring in the prioritization solutions. The areas with a 0 value contained only GMUs.

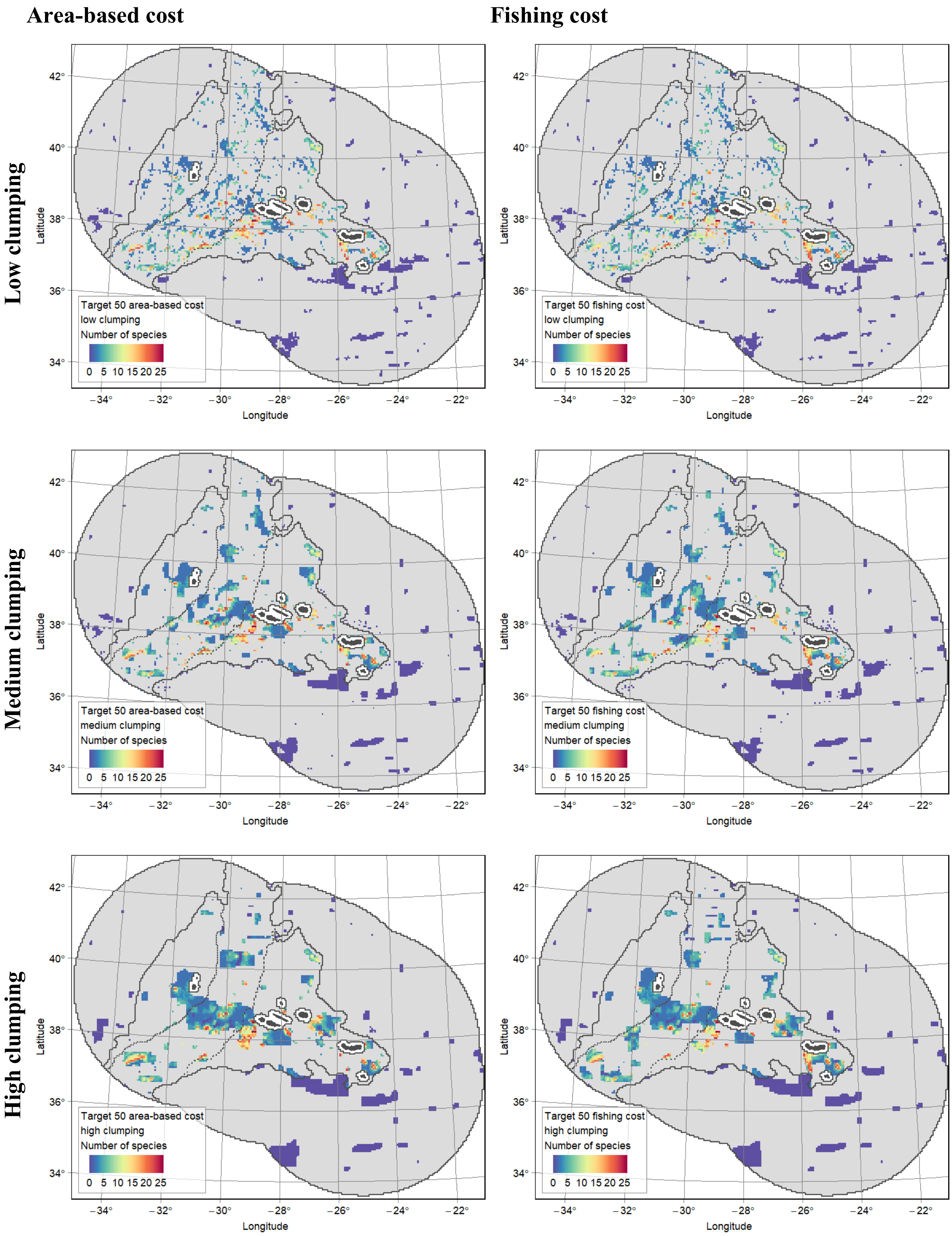


Figure 59. Number of features occurring in the prioritization solutions for the overarching goal of restoring deep-sea fish stocks while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores with the scenario: 50% target, 3 different configurations (high, medium and low clumping), and fisheries-based cost. The areas with a 0 value contained only GMUs.

7. Performance assessment of the different scenarios

The implementation of different fisheries closed area designs may produce different short-, medium- and long-term outcomes depending on the extent (size), design (shape), and location (placement and spacing) of such closures. Here, we assessed the performance of the different scenarios using metrics to evaluate six designed criteria (Table 23). In short, this work clearly showed that the systematic conservation planning scenarios are highly dependent on the overall goal to be achieved and that no single solution can obtain the best performance on the different design criteria. This implies that 1) the overall goal of the closed area needs to be agreed and 2) trade-offs in scenario performance across network criteria will have to be agreed.

7.1 Viability, adequacy, and replication

In general terms, the size and the proportion of the spatial planning area in the network increased with increasing representation targets (Table 24; Figure 60). However, the final representation targets were never achieved, mostly in the "data-poor abyssal" area. This is because the representation targets for deep GMUs were kept low since the data deficiency hampers a useful development of the prioritizing approach. Not surprisingly, networks optimized with low clumping achieve a much better replication than the networks based on high clumping. However, many small fisheries closed areas may be difficult to implement, comply and enforce. The number of priority areas decreases with the degree of clumping (high 40, medium 65, low 224; Figure 60), while the average sizes of priority areas increases (high 1845km^2, medium 965km^2, low 273km^2). Is should also be highlighted that the fishing footprint and the fishing effort in the network can be significantly reduced if an varying fishing-cost model is used instead of an area-based cost (Figure 61). In fact, the loss of fishing grounds can be maintained at about 15% for fishing cost scenarios, except for the scenarios with 30% and 50% spatial planning area targets (Table 24). If not considering the fishing cost, the prioritizing approach will favour the best PU to achieve the management goals and the overlap with existing fishing grounds is much higher; about 19% with the exceptions of the scenarios for the 30% and 50% spatial planning area targets. In most of the scenarios with 10% and 15% spatial planning area targets the loss of fishing effort is about 20%.

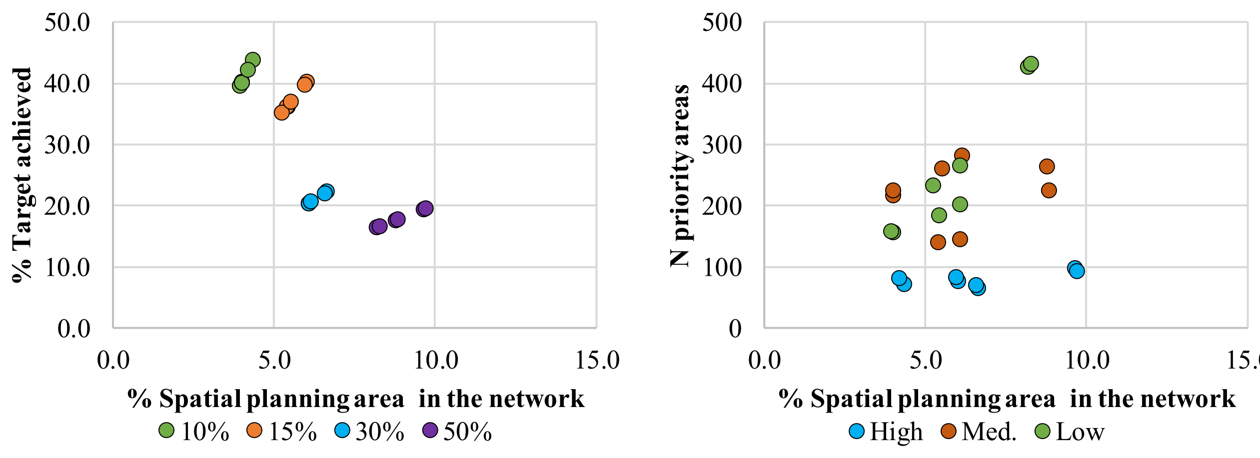


Figure 60. The proportion of spatial planning area targets achieved (left) and the number of priority areas (right) and for each of the 24 scenarios by spatial planning area covered in each network.

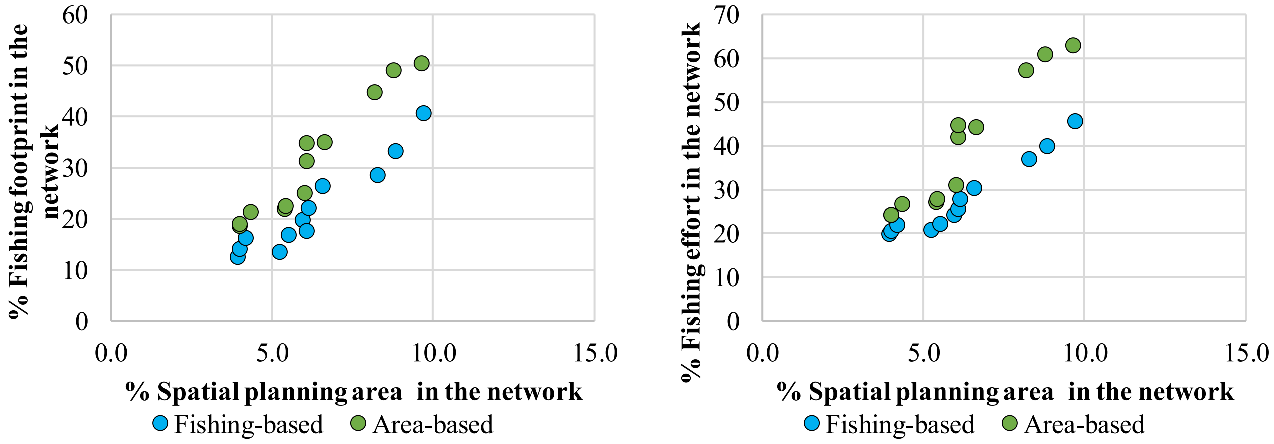


Figure 61. Proportion of fishing footprint (left) and fishing effort (right) in the network for each of the 24 scenarios by spatial planning area covered in each network.

7.2 Connectivity

Network designs based on low clumping achieved both smaller average and maximum distances between closed areas (Figure 62; Table 24). Although connectivity may be important aspect to be considered in the design of networks of closed areas (Magris et al., 2018), we cannot evaluate if the distance values estimated here will limit the success of the network. This is because there are fundamental gaps of knowledge on connectivity in deep-sea fauna and its implications for marine reserve design. For a reference, the average daily displacements of blackspot seabream and conger eel were estimated to be 11 and 5.6 km·day^{-1} (Afonso et al., 2014; Pereira et al., 2017); whereas the 75th percentile median dispersal distance were estimated as being 103 km for vent invertebrates and 74 km for other deep-sea benthic invertebrates (Dunn et al., 2018; based on Baco et al., 2016, Ross et al., 2016; Hilário et al., 2015). Using these latter values as a reference, it clear that most closed areas in the network are not isolated and most likely highly connected within the spatial planning area (Figure 62). However, network designs based on low clumping obtained better connectivity metrics, followed by those based on medium clumping.

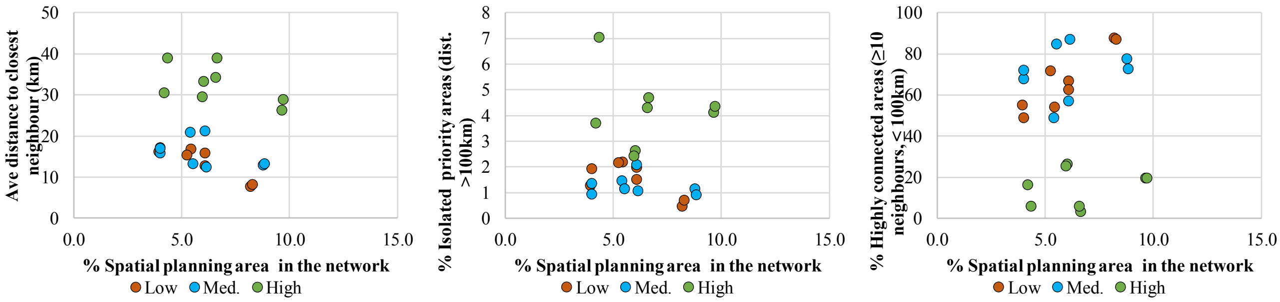


Figure 62. Connectivity metrics. Average distance to closest neighbour (top), proportion of isolated priority areas (bottom left), and proportion of highly connected areas (bottom right) in the network for each of the 24 scenarios by spatial planning area covered in each network.

7.3 Representativity

In general, the conservation planning scenarios aiming at achieving lower spatial planning area targets (10% and 15%) were more successful in achieving good representativity (Figure 63; Table 25). This is an artefact of the implementation of prioritization approach since, we limited the target for most GMUs low because of the lack of data to inform the data driven approach (Section 5.4.1). No clear effect of clumping or cost model were observed on most the representativity metrics (Figure 63). In general, the proportion of depth strata included in the network increase with the increased target and, apparently, also increase from low to high clumping (Figure 64).

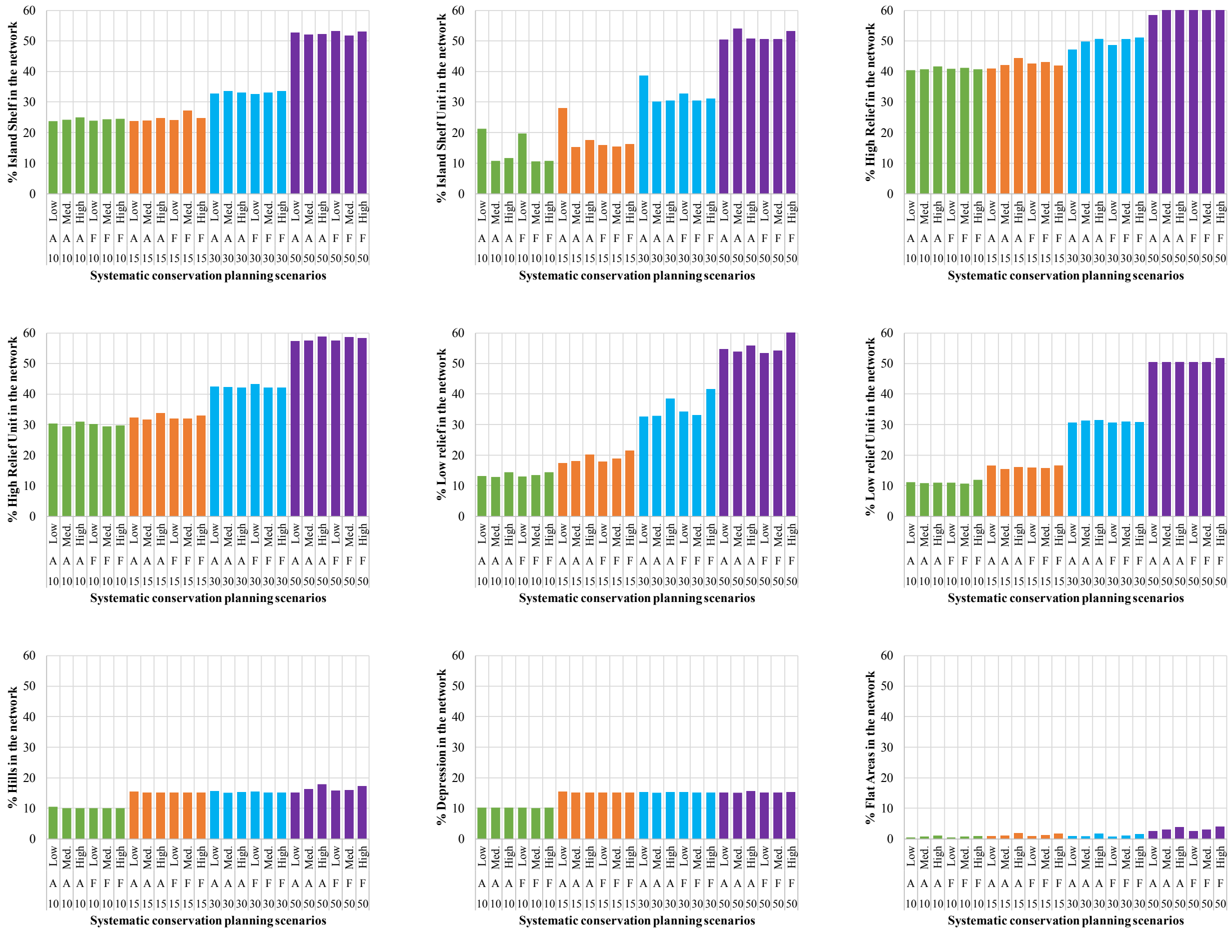


Figure 63. Proportion of representativity units that achieved the target for each of the 24 scenarios.

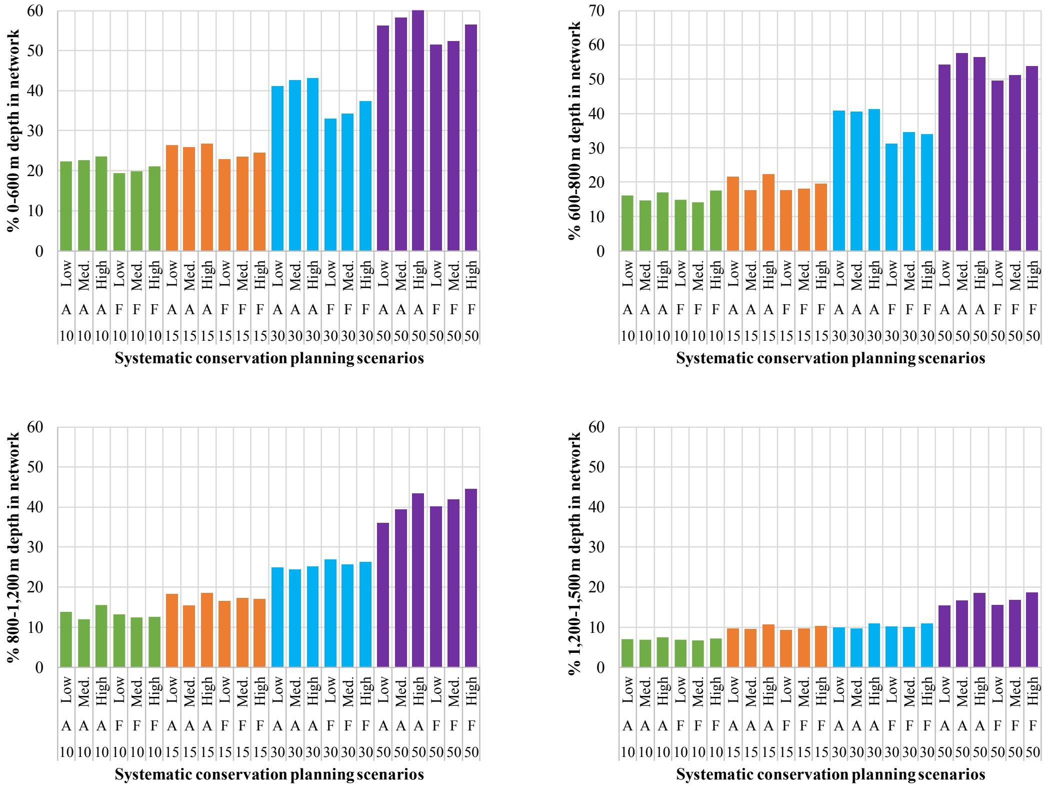


Figure 64. Proportion of each depth strata included in the network for each of the 24 scenarios.

7.4 Important resources

Representation targets for important resources were achieved in all scenarios regardless of the prioritization configurations (Table 26). However, scenarios accounting for area-based cost included more habitat for fish, habitat-structuring corals, and VMEs corals when compared to fisheries-based cost (Figure 65.). No differences were apparent for deep-water sharks and rays' habitat included in the prioritization solutions. Also no differences were observed on the average quality of the habitat included in the prioritization solutions (Table 26).

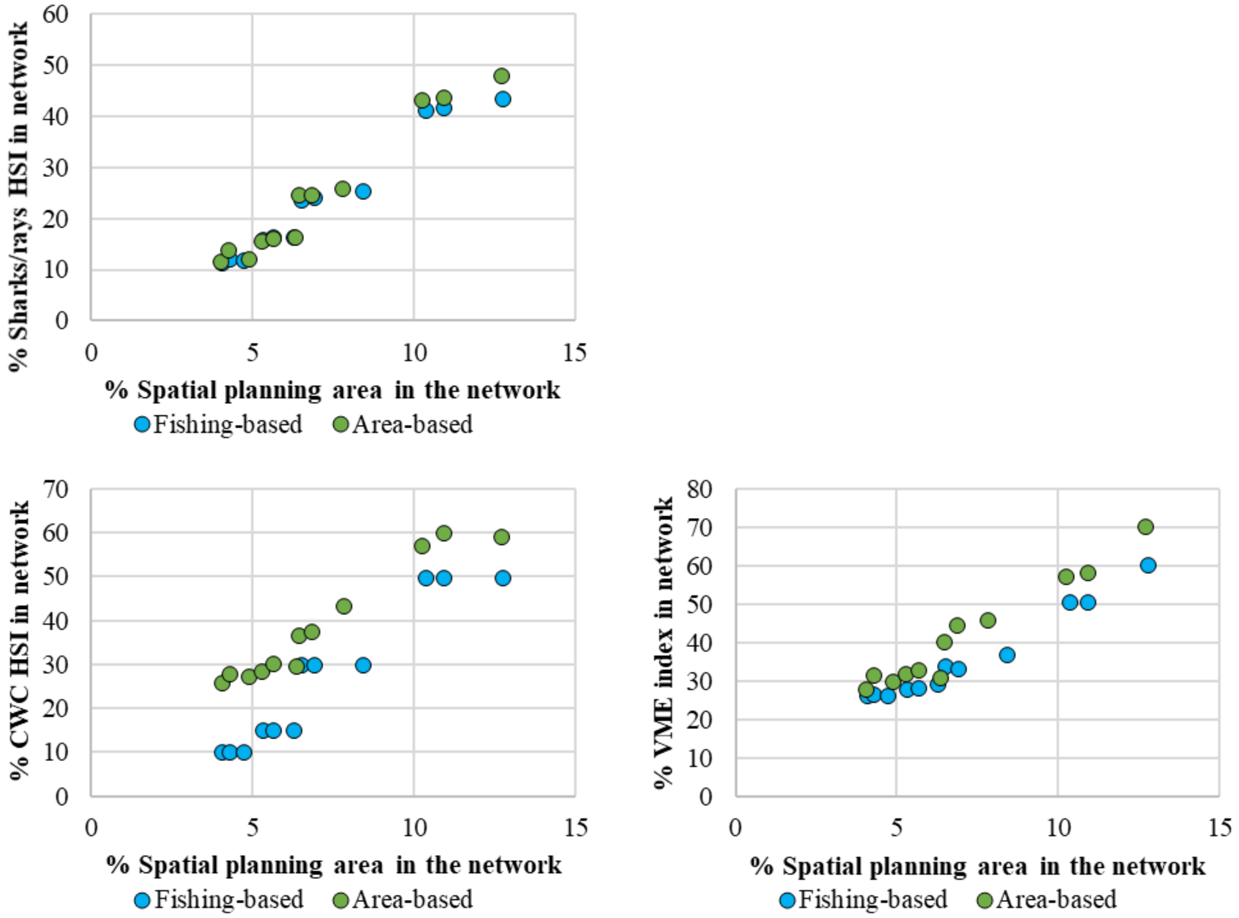


Figure 65. Proportion of fish HSI (top left), sharks and rays HSI (top right), CWC HSI (bottom left), and VME index (bottom right) in network for each of the 24 scenarios by spatial planning area covered in each network.

Table 24. Performance assessment of the “viability and adequacy”, “replication” and “connectivity” design criteria for different conservation planning scenarios developed for deep Azores ecosystems. These scenarios considered a) four different spatial planning area targets (10%, 15%, 30%, and 50%), b) three different configurations of priority areas for management and conservation design (high, low and medium clumping), and c) two cost models (fishing cost, and area-based cost).

Spatial planning area targets	10%						15%						30%						50%					
Cost	Area-based			Fishing-based			Area-based			Fishing-based			Area-based			Fishing-based			Area-based			Fishing-based		
Clumping	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High
Viability and adequacy																								
Size of the network (x1000 km^2)	37.9	37.8	41.2	37.3	37.9	39.7	51.2	51.1	57.0	49.7	52.3	56.2	57.5	57.6	62.9	57.4	58.2	62.3	77.3	83.1	91.1	78.4	83.7	91.7
% Spatial planning area	4.0	4.0	4.4	4.0	4.0	4.2	5.4	5.4	6.0	5.3	5.5	6.0	6.1	6.1	6.7	6.1	6.2	6.6	8.2	8.8	9.7	8.3	8.9	9.7
% "Data-rich" area	6.6	6.4	7.1	6.5	6.4	6.7	9.3	9.0	10.3	8.8	9.3	10.0	10.7	10.4	11.6	10.7	10.5	11.4	16.2	17.6	19.6	16.5	17.8	19.7
% "Data-poor abyssal" area	2.7	2.8	3.0	2.7	2.8	2.9	3.5	3.6	3.9	3.5	3.6	3.9	3.8	3.9	4.1	3.7	3.9	4.1	4.1	4.3	4.6	4.1	4.3	4.6
% Spatial closure target achieved	40.2	40.1	43.7	39.5	40.1	42.1	36.2	36.1	40.3	35.1	36.9	39.7	20.3	20.3	22.2	20.3	20.6	22.0	16.4	17.6	19.3	16.6	17.7	19.4
% "Data-rich" spatial target achieved	66.3	63.6	71.0	64.5	63.5	67.2	61.8	59.9	68.5	58.6	61.9	66.8	35.6	34.8	38.7	35.6	35.1	38.1	32.4	35.3	39.3	33.1	35.6	39.5
% "Data-poor abyssal" target achieved	26.8	28.1	29.7	26.7	28.1	29.3	23.1	23.9	25.8	23.1	24.2	25.9	12.5	12.9	13.8	12.4	13.1	13.8	8.2	8.6	9.1	8.2	8.6	9.2
% Priority areas in "data-poor abyssal"	44.2	46.3	45.1	44.8	46.4	46.0	42.2	43.9	42.4	43.5	43.4	43.1	40.8	42.1	41.1	40.6	42.2	41.4	33.1	32.2	31.2	32.6	32.2	31.3
Average size of priority areas (km^2)	243	175	581	236	169	490	280	367	750	213	201	677	217	400	983	284	207	889	182	316	939	182	372	996
% Network already protected	4.2	4.6	4.3	4.4	4.4	4.2	3.0	3.7	3.2	3.4	3.4	3.3	3.4	3.5	3.1	2.7	3.4	3.1	2.6	2.6	2.2	2.6	2.4	2.2
% Fishing footprint in the network	18.9	18.6	21.2	12.4	14.0	16.1	22.5	21.9	24.9	13.4	16.8	19.6	31.3	34.7	35.0	17.5	22.0	26.4	44.7	49.0	50.5	28.4	33.1	40.6
% Fishing effort in the network	24.0	24.1	26.6	19.8	20.4	21.7	27.7	27.2	31.0	20.7	22.2	24.0	41.9	44.6	44.2	25.5	27.9	30.2	57.1	60.8	62.8	37.0	39.9	45.5
Replication																								
N priority areas	156	216	71	158	224	81	183	139	76	233	260	83	265	144	64	202	281	70	426	263	97	431	225	92
N priority areas larger than 100km^2	70	54	39	71	53	46	91	78	45	103	67	46	96	87	46	99	82	46	173	89	65	180	79	61
Connectivity																								
Ave distance to closest neighbour (km)	17.1	15.8	38.9	16.1	16.9	30.5	16.8	20.9	33.3	15.3	13.1	29.5	12.8	21.2	38.9	15.8	12.3	34.1	7.6	12.9	26.2	8.2	13.1	28.9
Max distance to closest neighbour (km)	224.7	186.0	216.3	148.4	137.6	230.0	152.6	233.1	204.1	152.6	179.0	209.4	156.2	148.1	240.0	152.6	181.2	240.0	152.6	130.9	144.3	152.6	125.1	145.1
% Isolated priority areas (dist. >100km)	1.9	0.9	7.0	1.3	1.3	3.7	2.2	1.4	2.6	2.2	1.2	2.4	1.5	2.1	4.7	2.0	1.1	4.3	0.5	1.1	4.1	0.7	0.9	4.4
% Network area that is isolated	0.7	0.1	16.9	0.6	0.2	15.0	0.8	1.0	7.8	0.9	0.9	8.5	0.7	7.4	9.5	0.7	0.5	8.9	0.2	0.2	6.3	0.4	0.1	5.9
% Highly connected areas*	48.7	67.6	5.6	55.1	71.9	16.1	54.1	48.9	26.3	71.7	84.6	25.3	66.8	56.9	3.1	62.4	86.8	5.7	87.6	77.6	19.6	87.0	72.4	19.6
% Network area that is highly connected	57.8	67.3	24.6	60.1	64.6	17.6	65.2	47.3	28.4	70.6	73.6	23.4	68.1	54.3	22.6	70.7	71.3	13.2	84.0	81.2	69.3	83.4	81.6	65.4

* ≥10 neighbours and max. distance to closest neighbour ≤ 100km

Table 25. Performance assessment of the “representativity” design criteria for different conservation planning scenarios developed for deep Azores ecosystems. These scenarios considered a) four different spatial planning area targets (10%, 15%, 30%, and 50%), b) three different configurations of priority areas for management and conservation design (high, low and medium clumping), and c) two cost models (fishing cost, and area-based cost).

Spatial planning area targets	10%						15%						30						50%					
Cost	Area-based			Fishing-based			Area-based			Fishing-based			Area-based			Fishing-based			Area-based			Fishing-based		
Clumping	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High
Representativity																								
Depth strata in the network																								
% 0-600 m depth in network	22.3	22.6	23.6	19.5	19.9	21.1	26.3	25.9	26.6	22.8	23.4	24.5	41.1	42.6	43.0	33.0	34.3	37.4	56.2	58.3	64.5	51.4	52.4	56.5
% 600-800 m depth in network	16.2	14.8	17.0	14.9	14.2	17.6	21.5	17.7	22.3	17.7	18.1	19.6	40.9	40.5	41.3	31.2	34.5	34.1	54.2	57.7	56.4	49.6	51.2	53.9
% 800-1200 m depth in network	13.8	11.9	15.5	13.1	12.4	12.5	18.2	15.3	18.5	16.5	17.3	16.9	24.8	24.3	25.1	26.9	25.5	26.2	35.9	39.4	43.4	40.1	41.9	44.5
% 1200-2500 m depth in network	7.0	6.8	7.4	6.8	6.7	7.2	9.6	9.5	10.6	9.3	9.6	10.4	9.9	9.7	10.9	10.1	9.9	10.9	15.4	16.7	18.4	15.6	16.9	18.6
% >2500 m depth in network	2.2	2.4	2.5	2.2	2.4	2.5	2.9	3.1	3.4	3.0	3.2	3.5	3.4	3.4	3.7	3.3	3.5	3.7	3.5	3.7	4.1	3.5	3.7	4.1
GMUs in the network																								
% Island Shelf included	23.7	24.2	24.9	23.9	24.3	24.4	23.7	23.9	24.7	24.1	27.2	24.7	32.7	33.5	33.1	32.5	33.0	33.5	52.7	52.1	52.2	53.2	51.7	53.0
% Island Shelf Unit included	21.2	10.7	11.7	19.7	10.5	10.7	27.9	15.3	17.6	15.9	15.5	16.1	38.6	30.1	30.4	32.8	30.4	31.2	50.3	54.1	50.8	50.6	50.6	53.2
% High Relief included	40.4	40.8	41.7	40.8	41.2	40.8	40.9	42.1	44.3	42.6	43.1	42.0	47.1	49.7	50.7	48.6	50.6	51.1	58.4	62.5	64.5	62.0	63.8	65.3
% High Relief Unit included	30.4	29.4	31.0	30.2	29.4	29.7	32.3	31.7	33.8	31.9	31.9	32.9	42.5	42.3	42.2	43.3	42.2	42.2	57.4	57.5	58.9	57.5	58.5	58.2
% Low relief included	13.1	12.9	14.5	13.0	13.5	14.4	17.4	18.0	20.2	17.9	18.8	21.4	32.5	32.8	38.5	34.3	33.1	41.6	54.7	54.0	55.8	53.4	54.3	63.6
% Low relief Unit included	11.1	10.8	11.1	10.9	10.7	12.0	16.5	15.4	16.0	15.8	15.8	16.6	30.5	31.3	31.5	30.6	31.1	30.7	50.5	50.5	50.5	50.4	50.5	51.7
% Depression included	10.2	10.1	10.2	10.2	10.1	10.2	15.4	15.1	15.1	15.1	15.1	15.1	15.2	15.1	15.3	15.3	15.1	15.1	15.2	15.2	15.6	15.2	15.1	15.3
% Flat area included	0.5	0.7	1.1	0.5	0.7	0.9	0.8	1.0	1.7	0.8	1.2	1.7	0.8	0.9	1.6	0.8	1.0	1.5	2.3	3.0	3.8	2.4	3.1	3.9
% Hills included	10.5	10.1	10.1	10.1	10.1	10.1	15.5	15.0	15.0	15.0	15.1	15.0	15.5	15.0	15.3	15.5	15.1	15.1	15.1	16.1	17.9	15.6	15.8	17.3
N GMUs achieved target	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Seamounts in the network																								
% Shallow smts in network (<800m)	27.8	27.0	31.3	23.5	23.5	27.8	31.3	29.6	37.4	27.0	27.0	29.6	46.1	44.4	40.9	32.2	33.0	33.9	51.3	54.8	55.7	47.0	45.2	48.7
% Inter. smts in network (800-1500)	14.4	15.9	10.6	15.2	14.4	13.6	17.4	18.2	16.7	16.7	21.2	16.7	16.7	15.2	18.9	22.7	21.2	18.9	28.0	26.5	25.0	37.1	30.3	27.3
% Deep smts the network (>1500m)	32.4	26.5	29.4	38.2	35.3	29.4	32.4	26.5	32.4	38.2	29.4	35.3	35.3	32.4	32.4	41.2	35.3	35.3	38.2	41.2	32.4	44.1	47.1	35.3

Table 26. Performance assessment of the first set of "important resources" design criteria for different conservation planning scenarios developed for deep Azores ecosystems. These scenarios considered a) four different spatial planning area targets (10%, 15%, 30%, and 50%), b) three different configurations of priority areas for management and conservation design (high, low and medium clumping), and c) two cost models (fishing cost, and area-based cost).

Spatial planning area targets	10%						15%						30						50%					
Cost	Area-based			Fishing-based			Area-based			Fishing-based			Area-based			Fishing-based			Area-based			Fishing-based		
Clumping	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High
Important resources *("data-rich" area)*																								
Commercially important fish																								
% Fish HSI in network	20.1	19.6	21.0	18.7	18.5	18.9	24.0	22.2	24.3	21.9	21.7	22.0	43.8	43.5	41.4	33.6	34.8	36.0	54.9	56.7	64.8	52.4	53.9	55.9
% Fish habitat (HSI > thershold) in network	22.5	22.3	24.5	20.9	21.3	21.5	28.0	25.6	29.5	24.0	24.5	24.5	41.8	42.4	42.2	33.8	34.6	35.3	57.9	59.0	61.2	51.1	51.5	53.1
Avg. fish HSI (0-1) in network	0.21	0.20	0.19	0.20	0.20	0.20	0.20	0.20	0.19	0.21	0.20	0.21	0.24	0.24	0.23	0.24	0.24	0.24	0.23	0.23	0.24	0.24	0.25	0.25
% Fish predicted abundance in network	22.8	22.3	24.4	21.5	21.7	22.4	27.0	25.3	27.9	24.6	24.9	25.0	44.8	44.7	42.8	35.1	36.8	38.0	55.1	58.4	63.2	52.7	53.9	55.9
% Fish HSI in "protect" (out fishing footprint)	1.28	1.30	1.42	1.50	1.33	1.34	1.40	1.34	1.46	1.56	1.36	1.51	1.55	1.42	1.62	2.03	1.81	1.68	1.80	1.65	1.84	2.17	2.11	1.87
% Fish HSI in "restore" (in fishing footprint)	18.9	18.3	19.6	17.1	17.2	17.5	22.6	20.9	22.8	20.3	20.4	20.5	42.3	42.1	39.8	31.5	33.0	34.3	53.1	55.1	62.9	50.2	51.8	54.0
Vulnerable deep-sea sharks/rays																								
% Sharks/rays HSI in network	14.0	12.7	14.9	12.8	12.6	13.4	19.0	16.7	19.3	16.8	17.2	17.8	28.4	28.1	29.3	25.5	25.6	27.0	42.8	44.4	45.4	42.2	42.9	44.3
% Sharks/rays habitat (HSI > thershold) in network	15.2	14.1	16.7	14.0	13.9	14.6	19.9	17.8	21.1	17.3	18.3	18.9	27.6	27.3	28.9	24.9	24.5	26.0	39.1	42.4	44.6	39.0	40.6	42.5
Avg. Sharks/rays HSI (0-1) in network	0.22	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.21	0.23	0.22	0.22	0.24	0.24	0.23	0.23	0.24	0.23	0.26	0.24	0.24	0.25	0.25	0.24
% Sharks/rays predicted abund. in network	14.9	13.0	15.8	13.1	12.9	14.5	19.7	16.9	20.3	17.0	17.4	18.6	32.7	31.2	33.5	28.3	28.4	30.6	46.9	48.6	50.0	46.0	47.3	48.6
% Sharks/rays HSI in "protect" (out fishing footprint)	4.79	4.32	5.36	5.53	5.00	4.84	7.00	6.14	7.18	7.83	7.38	7.40	7.81	6.88	8.30	10.88	9.07	9.47	12.48	12.93	14.77	17.11	16.58	16.12
% Sharks/rays HSI in "restore" (in fishing footprint)	9.2	8.4	9.5	7.3	7.6	8.5	12.0	10.6	12.1	8.9	9.8	10.4	20.6	21.2	21.0	14.6	16.5	17.5	30.3	31.5	30.7	25.0	26.3	28.1

Table 27. Performance assessment of the second set of "important resources" design criteria for different conservation planning scenarios developed for deep Azores ecosystems. These scenarios considered a) four different spatial planning area targets (10%, 15%, 30%, and 50%), 2) three different configurations of priority areas for management and conservation design (high, low and medium clumping), and c) two cost models (fishing cost, and area-based cost).

Spatial planning area targets	10%						15%						30						50%					
Cost	Area-based			Fishing-based			Area-based			Fishing-based			Area-based			Fishing-based			Area-based			Fishing-based		
Clumping	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High
Important resources *("data-rich" area)*																								
Habitat-structuring CWC																								
% CWC HSI in network	29.8	29.3	33.0	27.6	28.2	28.6	33.8	32.3	37.0	30.8	32.1	30.9	42.9	44.7	44.9	37.7	40.0	40.3	58.9	61.2	61.7	56.1	57.3	57.9
% CWC habitat (HSI > thershold) in network	21.0	20.9	25.1	19.7	20.6	21.4	26.0	24.8	30.2	22.6	24.6	24.7	34.4	37.0	38.5	30.3	30.6	31.9	50.2	53.4	53.7	46.4	47.5	47.7
Avg. CWC HSI (rescaled to 0-1) in network	0.29	0.29	0.27	0.29	0.28	0.28	0.26	0.27	0.25	0.28	0.27	0.26	0.26	0.25	0.24	0.26	0.26	0.26	0.24	0.24	0.24	0.25	0.25	0.25
% CWC HSI in "protect" (out fishing footprint)	4.1	4.0	5.6	4.4	4.7	4.7	5.9	5.5	7.0	6.4	6.3	6.0	5.8	5.3	7.4	7.8	6.5	7.0	7.6	8.0	8.7	12.1	10.9	9.6
% CWC HSI in "restore" (in fishing footprint)	25.7	25.3	27.3	23.2	23.5	23.9	27.9	26.8	30.0	24.5	25.8	25.0	37.1	39.4	37.6	29.9	33.5	33.2	51.3	53.2	53.0	44.0	46.4	48.2
Observed habitat-structuring CWC																								
% CWC records in network	41.8	44.9	50.8	43.7	42.3	44.2	45.8	48.6	57.3	44.6	47.2	46.5	61.4	61.4	65.8	54.9	60.4	66.6	87.0	89.0	91.4	86.5	86.5	86.5
% CWC records in "protect" (out fishing footprint)	12.4	14.3	14.8	14.3	12.9	14.8	12.9	14.8	14.8	14.5	16.4	15.4	12.9	12.9	13.4	15.0	15.9	15.9	18.4	18.4	19.2	20.8	20.8	20.3
% CWC records in "restore" (in fishing footprint)	29.4	30.6	36.0	29.4	29.4	29.4	32.9	33.8	42.5	30.1	30.8	31.1	48.5	48.5	52.3	39.9	44.5	50.7	68.7	70.6	72.2	65.7	65.7	66.2
Inferred VMEs																								
% VME index in network	28.8	29.7	33.7	27.6	26.8	31.4	35.8	33.7	41.1	29.8	32.7	34.6	45.4	45.7	46.4	36.3	36.4	37.0	58.6	58.8	64.0	51.8	53.1	55.0
Avg. VME index (rescaled to 0-1) in network	0.89	0.88	0.88	0.89	0.89	0.88	0.86	0.88	0.86	0.86	0.87	0.86	0.86	0.86	0.85	0.86	0.85	0.87	0.85	0.85	0.86	0.86	0.86	0.84
% VME index in "protect" (out fishing footprint)	6.8	7.6	9.1	7.7	6.3	10.5	10.0	9.2	12.0	9.2	10.8	13.1	9.5	8.7	11.6	12.0	9.7	10.5	14.5	13.4	16.7	16.7	17.5	17.9
% VME index in "restore" (in fishing footprint)	22.0	22.1	24.7	19.9	20.5	20.8	25.8	24.5	29.1	20.5	21.9	21.5	35.9	37.1	34.8	24.3	26.7	26.5	44.1	45.4	47.3	35.1	35.6	37.1

8. Ecosystem-level forecasted outcomes

8.1 Ecosystem and fisheries projections under a BAU scenario

The Azores Ecospace model was used to forecast ecosystem and fisheries effects over twenty years, in response to multiple management schemes, including the Business as Usual Scenario. Under the Business as Usual Scenario, assuming *status quo* levels of fishing effort, the biomass of the largest majority of exploited benthic fish species in the Azores were predicted to decrease over the following twenty years (Figure 66). The strongest biomass reductions were predicted for *Phycis phycis* and *Pontinus kuhlii* (both -48%), followed by *Beryx decadactylus* (-24%), *Mora moro* (-15%), *Raja clavata* (-13%), *H. dactylopterus* (-11%), large-sized demersal fish (-6%), *Pagellus bogaraveo* (-3%), *Conger conger* (-2%), *Pagrus pagrus* (-2%), large-size shallow water fish (-2%), benthic sharks and rays (-1%). Small biomass increases were solely estimated for *Beryx splendens* and the medium-size shallow water fish group. In response to the biomass decreases, predicted under the BAU scenario, the catches were also expected to decrease over time (Figure 66).

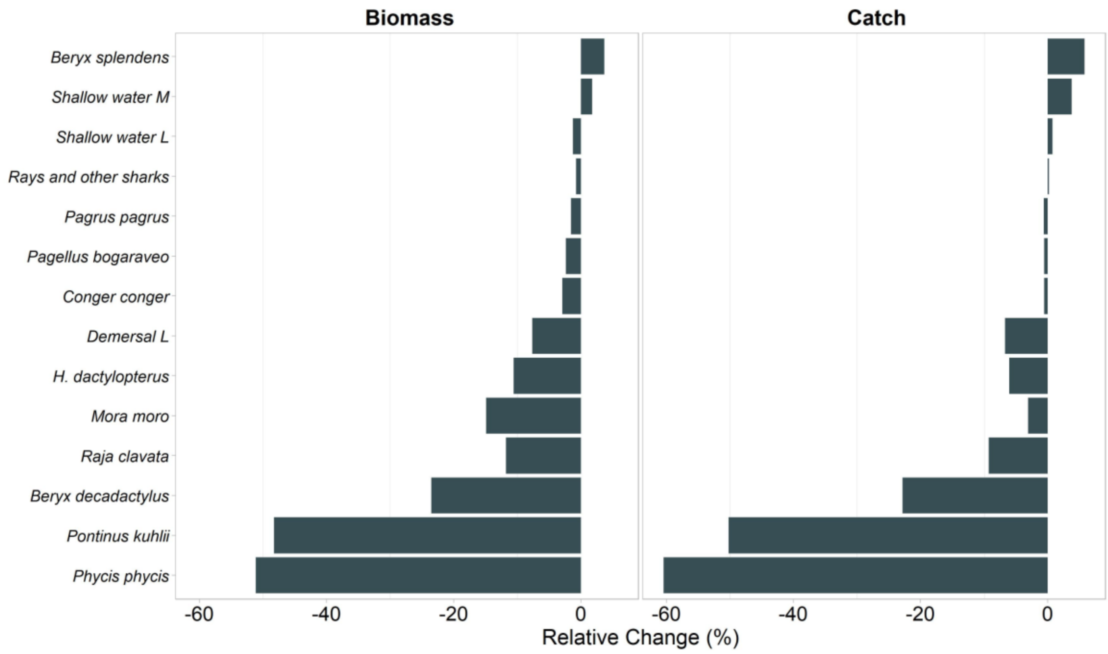


Figure 66. Relative changes in biomass and catch of benthic commercial species, over the following 20 years, predicted with Ecospace, under status quo levels of fishing effort (BAU scenario, dark grey bars).

8.2 Ecosystem and fisheries projections under different management scenarios

8.2.1 Projected changes in biomass

The Azores Ecospace model projected that the implementation of all management strategies would have positive impacts in the overall biomass of benthic fish species, in comparison to the business as usual scenario (Figure 67, Figure 68). In what concerns to all deep-sea benthic fish combined, we noted that the implementation of a MPA strategy is projected to have lower positive outcomes when compared to the reduction in fishing effort strategy (FE strategy). However, it should be emphasised that rebuilding fish stocks should not be considered the only management goal to be achieved and that the MPA strategy have additional positive outcomes (e.g. protection of VMEs) not measured with this approach. Not surprisingly, the greatest increases in biomass of all deep-sea benthic fish combined were projected under the scenarios that considered the implementation of no-take areas accompanied with reduction in fishing effort of deep-sea gears proportional to the effort lost within each MPA network (under the MPA + FE strategy). Also not surprisingly, the highest amounts of biomass increases were projected under scenarios that considered the greatest levels of protection and fishing effort reductions (>30% spatial planning closure and > 20% fishing effort reduction) (Figure 67, Figure 68).

Despite the overall trends described above, projected responses to different management strategies were species specific (Figure 67, Figure 68). The biomass of most species were projected to enhance under most scenarios. This was notably the case of *C. conger, P. kuhlii, R. clavata, B. splendens* and *P. bogaraveo*. The positive impact of fishing closure size on the relative biomass increase was mostly evident on top-predators (e.g., *C. conger* and *R. clavata*). On the contrary, our the model projected negative effects of the MPA strategy, when compared to the BAU scenario, in the biomass of coastal and shallow water species, namely *P. phycis*, *P. pagrus* and large-size shallow water fish. The negative impacts of the MPA strategy seemed to amplify with increasing fishing closures targets. This effect may be linked to a displacement of fishing effort to non-protected coastal and shallower fishing grounds. For this three species, the reduction of fishing effort strategy was projected to yield the largest increased in biomasses. Species and functional groups that are not particularly responsive to fishing pressure showed limited responses to the all management strategies and respective scenarios (namely, large-size demersal fish, *H. dactylopterus, Beryx decadactylus*). According to model outcomes, the dynamic of these species is mostly controlled by bottom-up processes that regulate food availability.

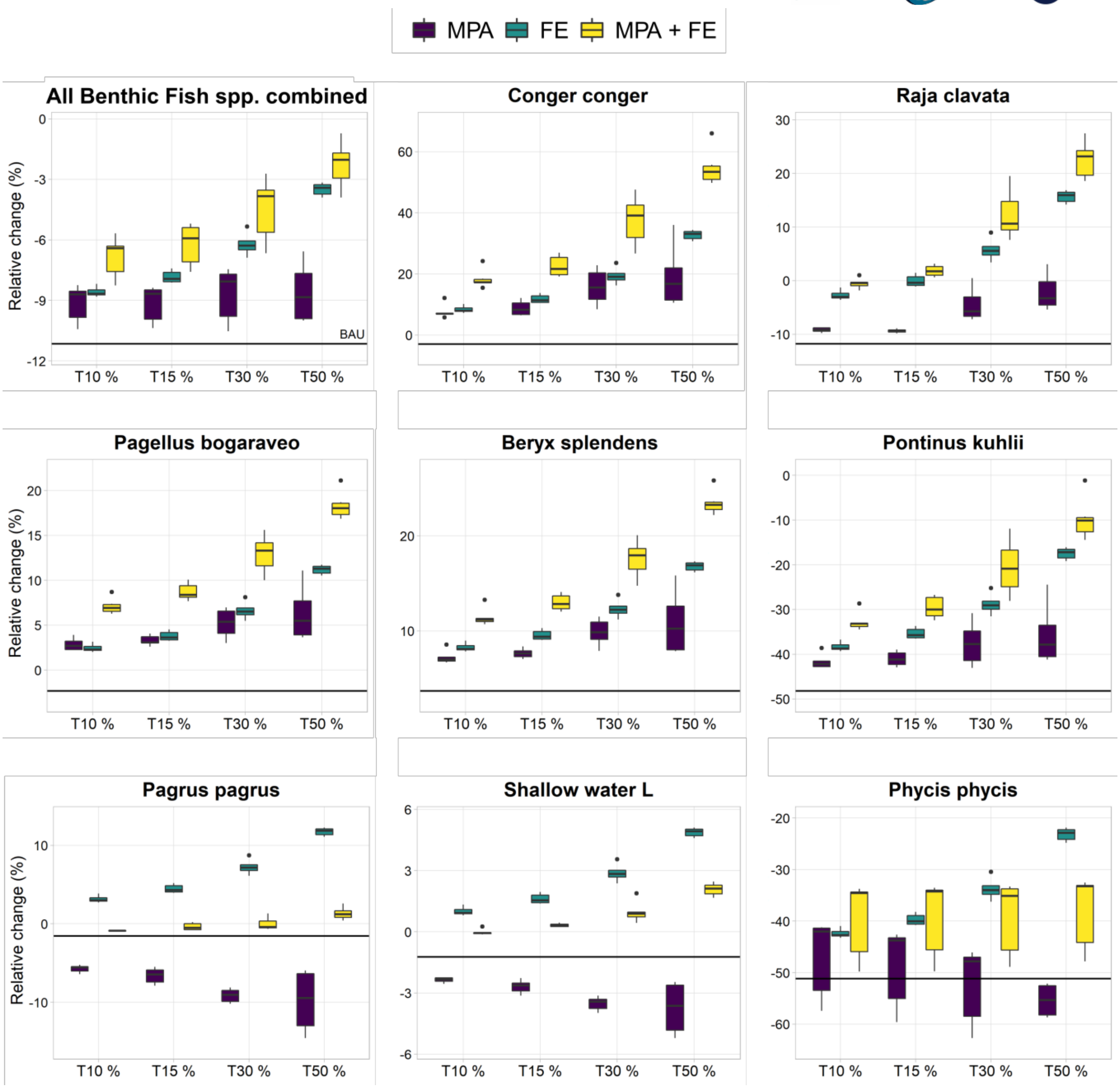


Figure 67. Relative changes in the biomass of all benthic fish species combined and commercially important fish groups forecasted after 20 years of Ecospace simulations for multiple scenarios of fishing restrictions under the MPA, MPA+FE and FE management strategies. T10%, T15%, T30%, and T50% corresponded, respectively, to 13%, 16%, 23%, 33% averaged reductions in fishing effort modelled in scenarios under the FE and MPA+FE strategy. The black line corresponds to the reference BAU scenario.

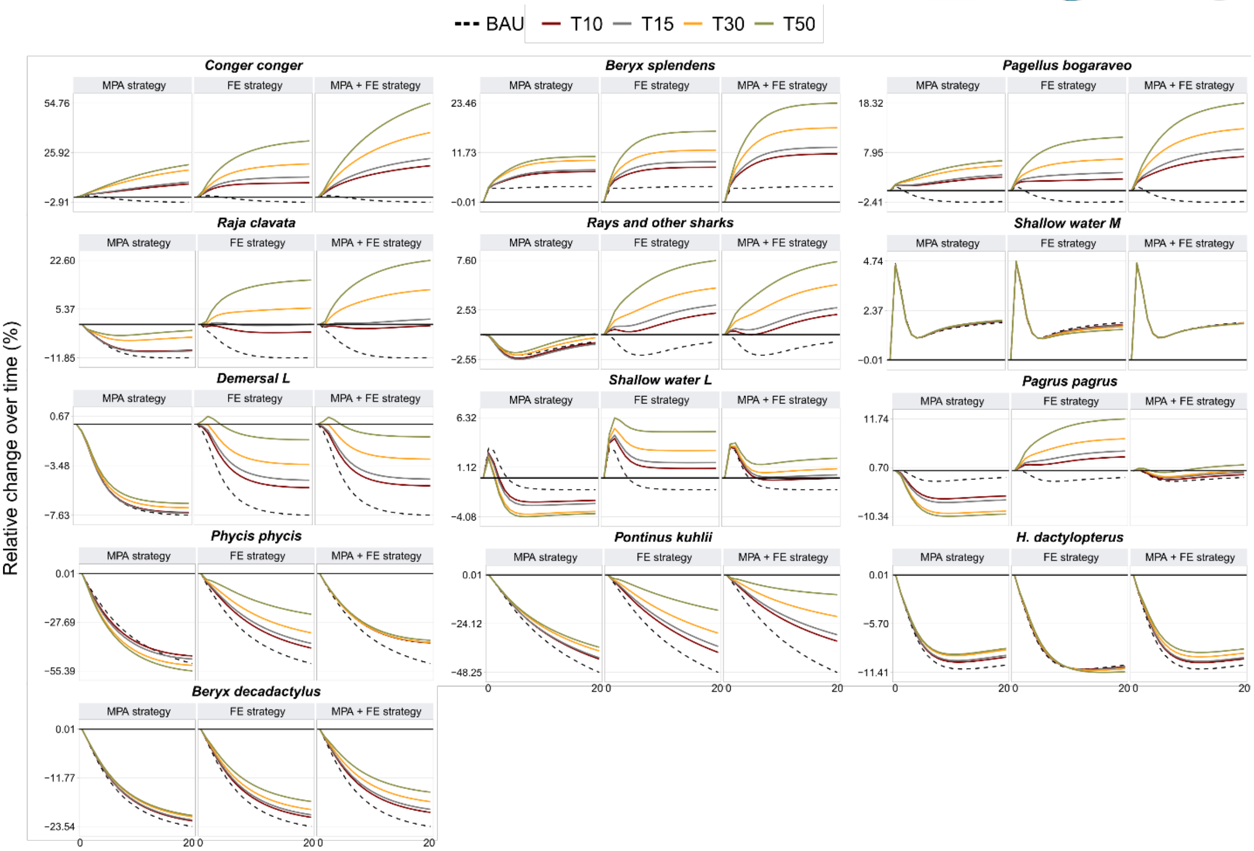


Figure 68. Relative temporal changes in the biomass of commercially important functional groups forecasted with Ecospace for multiple scenarios of fishing restrictions under the MPA, MPA+FE and FE management strategies. T10%, T15%, T30%, and T50% corresponded, respectively, to 13%, 16%, 23%, 33% averaged reductions in fishing effort modelled in scenarios under the FE and MPA+FE strategy. Estimates within each projection were averaged among clumping designs and cost model scenarios. In the x-axis, 0 corresponds to first year of simulation and 20 to the maximum year of the projections.

8.2.2 Projected changes in fisheries catch

Our ecosystem model projections showed that the implementation of most management strategies would have negative impact in the overall catch of benthic fish species, when compared to the business as usual scenario (Figure 69, Figure 70). In general, the decreased available fishing grounds (MPA strategy) and the reduction of fishing effort (FE strategy) were projected to decrease the annual catches despite of the increase in biomass. Not surprisingly, pronounced restrictions (i.e., large MPAs and/or high effort reductions) resulted into great catch losses. However, the displacement of fishing effort to shallow and coastal waters under the MPA strategy was projected to increase the catch of *P. pagrus* and large-size shallow water fish, relatively to the BAU scenario (Figure 69, Figure 70), leading to biomass decays. For these two species, the management strategies that encompass a reduction in fishing effort (FE and MPA+FE) were projected to produce loss of catch. It is interesting to note that our model projected an increase in catch under FE reduction strategies for both *P. phycis* and *P. kuhlii*. These were the only two species were an increased in biomass and catch were projected (under the FE strategy only).

According to model projections (which might not be correct), most commercially important benthic species, including *P. bogaraveo*, are currently being sustainably harvested (F<MSY), and fishing restrictions would therefore impose negative fisheries impacts. However, for species showing signs of overexploitation (e.g., *P.*

phycis and *P. kuhlii*), fishing effort reductions could indeed improve the recovery of the stock, relatively to the BAU scenario. For these particular species, yields from scenarios under the MPA + FE strategy, tended to approach the BAU quantities by the last years of the simulation. This trend was also visible in species that have high fishing mortality rates (e.g., *Conger conger* and *Raja clavata),* namely in scenarios under the FE strategy.

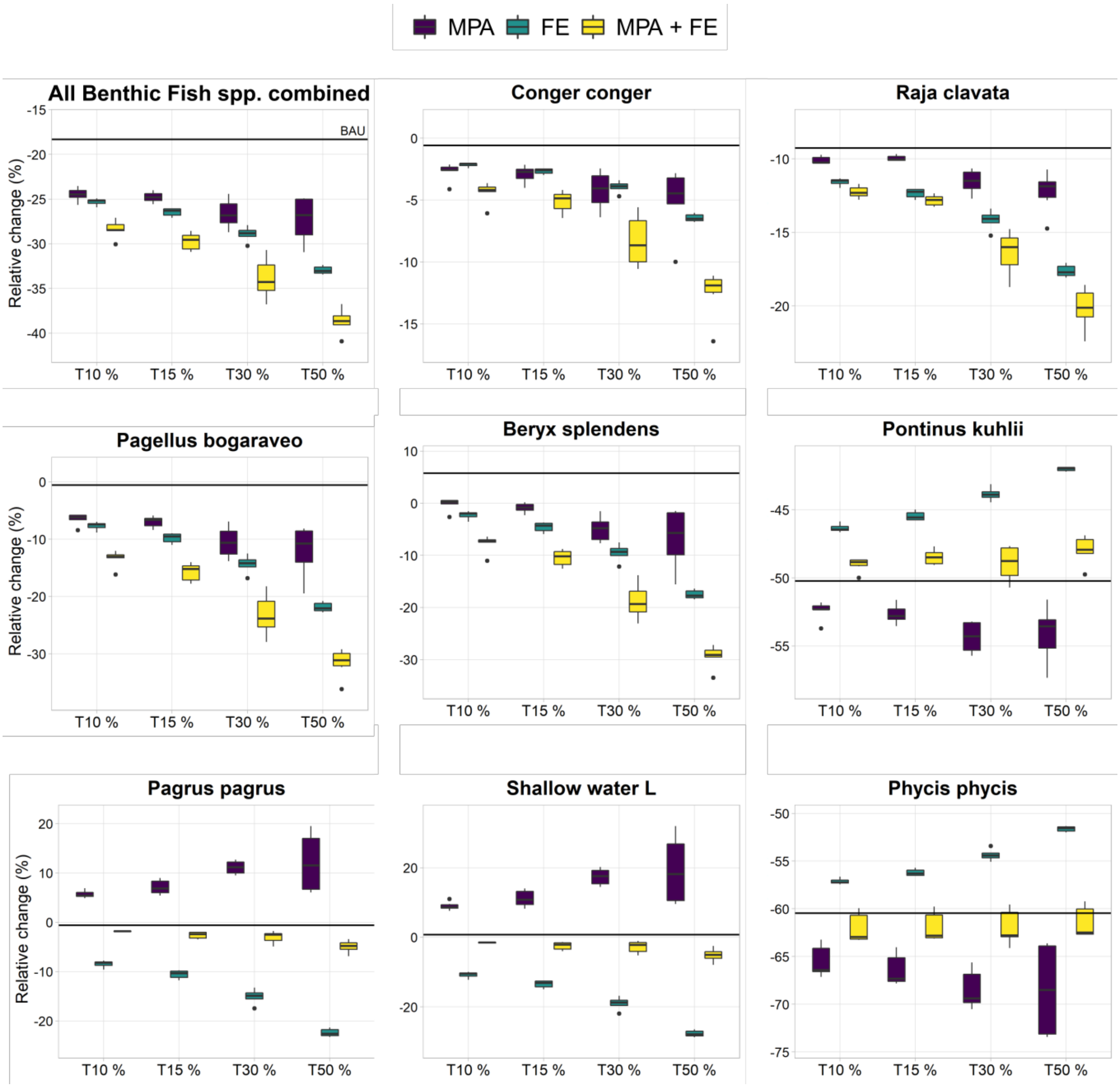


Figure 69. Relative changes in the catch of all benthic fish species combined and several functional groups forecasted after 20 years of Ecospace simulations for multiple scenarios of fishing restrictions under the MPA, MPA+FE and FE management strategies. T10%, T15%, T30%, and T50% corresponded, respectively, to 13%, 16%, 23%, 33% averaged reductions in fishing effort modelled in scenarios under the FE and MPA+FE strategy. The black line corresponds to the reference BAU scenario.

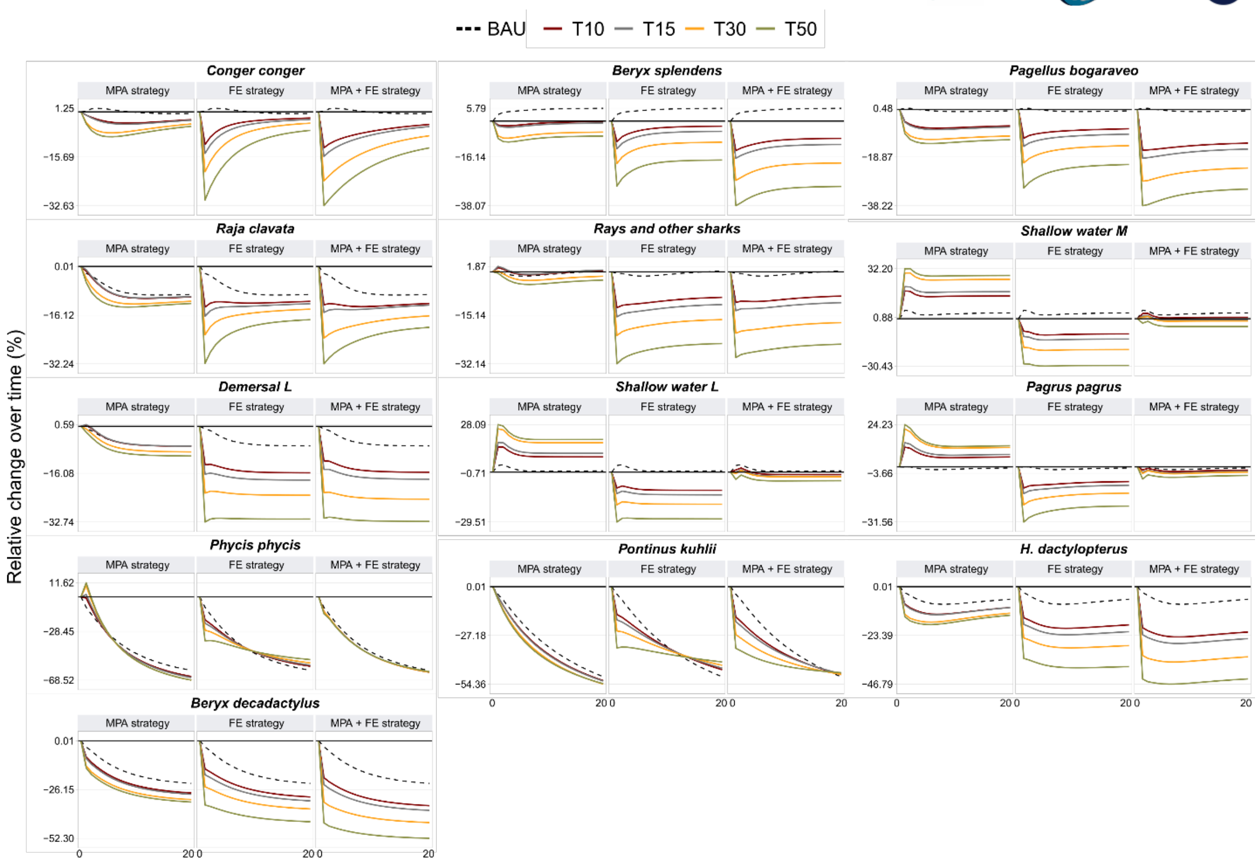


Figure 70. Relative temporal changes in the catch of commercially important functional groups forecasted with Ecospace for multiple scenarios of fishing restrictions under the MPA, MPA+FE and FE management strategies. T10%, T15%, T30%, and T50% corresponded, respectively, to 13%, 16%, 23%, 33% averaged reductions in fishing effort modelled in scenarios under the FE and MPA+FE strategy. Estimates within each projection were averaged among clumping designs and cost model scenarios. The black dashed line corresponds to the reference BAU scenario. In the x-axis, 0 corresponds to the year before implementation and 20 to the maximum year of the projections.

8.2.3 Projected changes in ecosystem structure

The analyses of the trophic spectrum suggested that the model projected an increase in biomass of the top predators, leading to trophic cascade effects down the food-web (Figure 71). The greatest biomass increase was estimated at trophic level 4.4, corresponding to the large-size bathydemersal group. The greatest increases were proportionally related with the size of the MPA network. The cascade effect resulted into biomass decreases at intermediate trophic levels (3.9-3.6) that due to predation-release stimulated biomass increases at even lower trophic levels (3.5-3.3). The spatial organization of trophic cascades within the marine reserves had no impact in the trophic spectra in the entire EEZ, suggesting that the structure and functioning of the food-web was not predicted to significantly change in response to the management strategies.

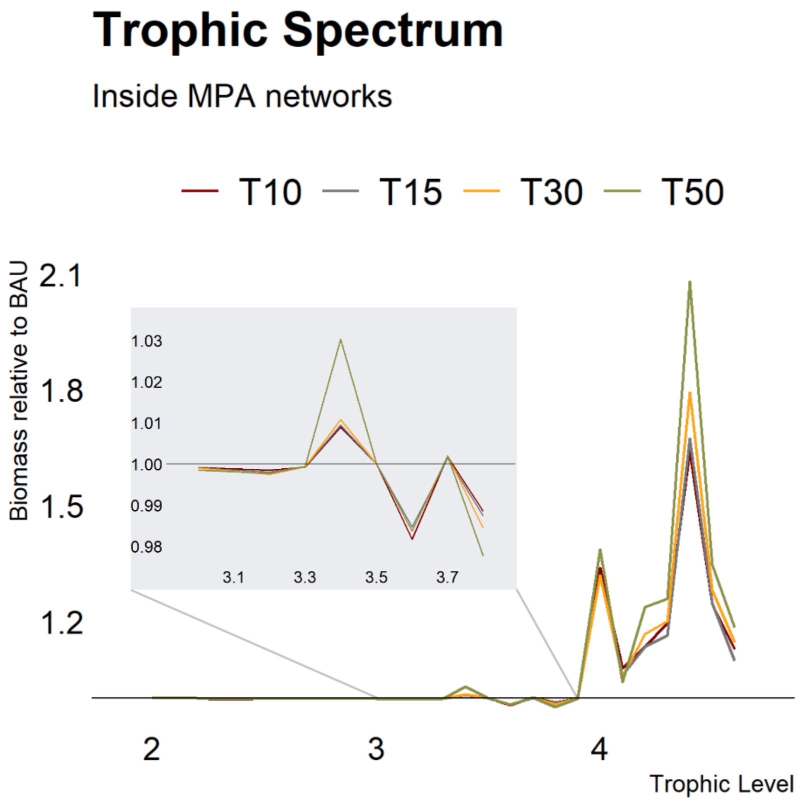


Figure 71. Change in the trophic spectrum relative do BAU for the last year of the simulations, estimated within MPA networks (high clumping design, area-based cost), under the MPA + FE strategy.

8.2.4 *Projected reserve effect*

Our model projections suggested that at the end of the simulation the suitable biomass of deep-sea fish species per squared kilometre would be greater within the MPA network in comparison to non-protected grounds (Figure 72). The projected differences of about 50% to 100% increase were not striking, since estimated biomass for the last year of the simulation did not double; as reported elsewhere (Halpern, 2003; Sale et al., 2005). Yet, since the biomass projected on non-protected grounds did not change after the implementation of the MPA network, it seems plausible to conclude that "reserve effects" were expected and that local depletion of deep-sea fish in adjacent waters were predicted to be unlikely (Figure 72).

Our model projected slightly higher reserve effects for the networks design with low and medium clumping when compared to high clumping and for the network design with fishing-based cost when compared to area-based cost (Figure 73). No major differences in reserve effect related to the size of the network (spatial planning targets) were observed for the scenarios with area-based cost, but our model projected higher reserve effects for lower spatial planning targets for scenarios under the fishing-based cost model.

Relatively to the coastal and shallow-water groups, the model projected no major reserve effects and local depletion of biomass on the adjacent non-protected grounds effects (Figure 73), which reflects the impact of excluding the coastal areas from the prioritization approach excluded coastal area areas (within 6nm from island shores) and reinforces the need for prioritization and ecosystem modelling approaches focussing on coastal areas.

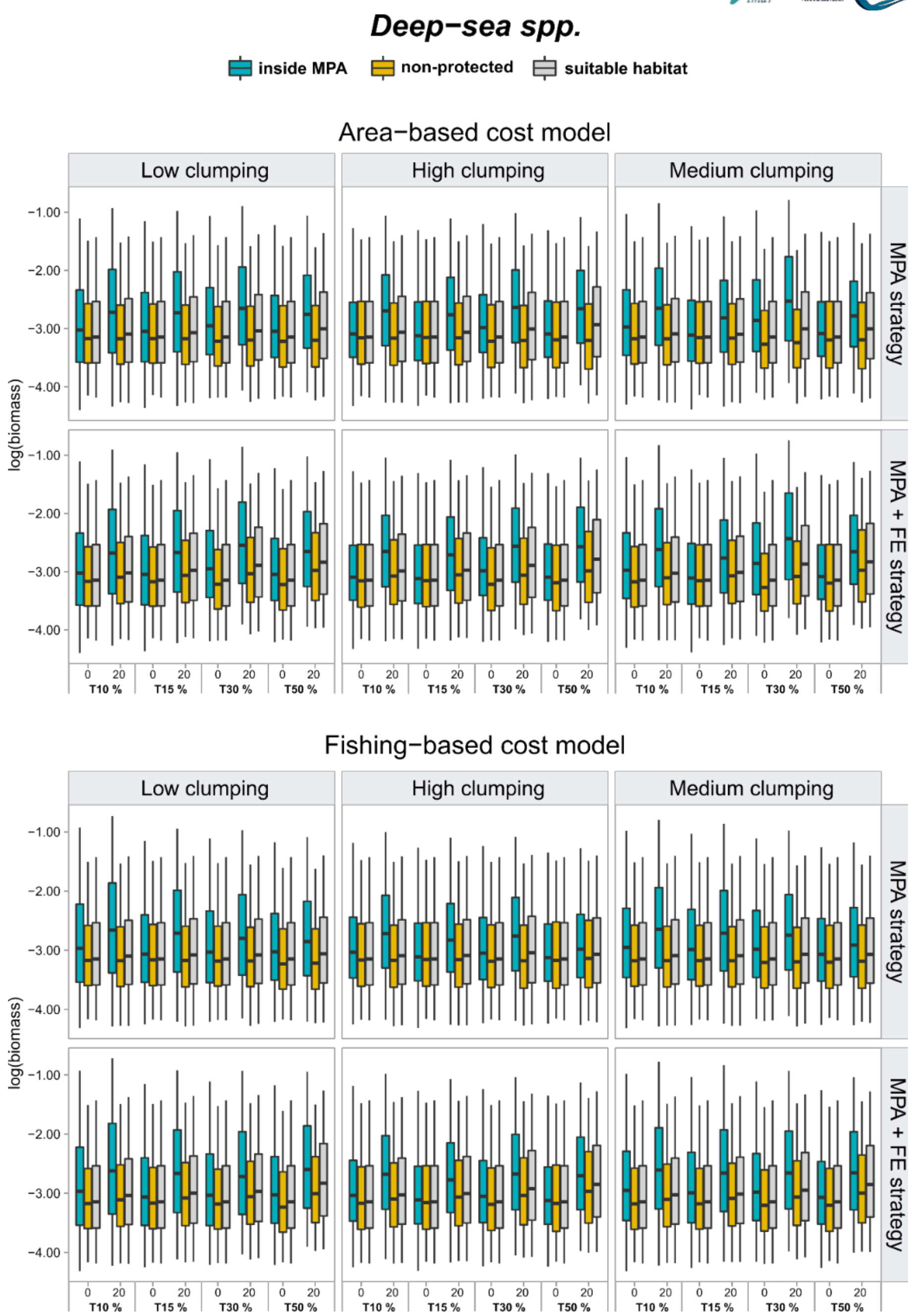


Figure 72. Projected reserve effect measured as the absolute suitable biomass (t·km^{-2}) of benthic deep-sea fish groups combined, estimated within the different conservation planning scenarios developed for the Azores deep-sea ecosystems and adjacent non-protected grounds, before (year 0) and after (year 20) the simulated implementation. These scenarios considered a) four different spatial planning area targets (10%, 15%, 30%, and 50%), b) three different configurations of priority areas for management and conservation design (high, low and medium clumping), c) two cost models (fishing cost, and area-based cost), and d) two management strategies that considered alternative levels of fishing effort.

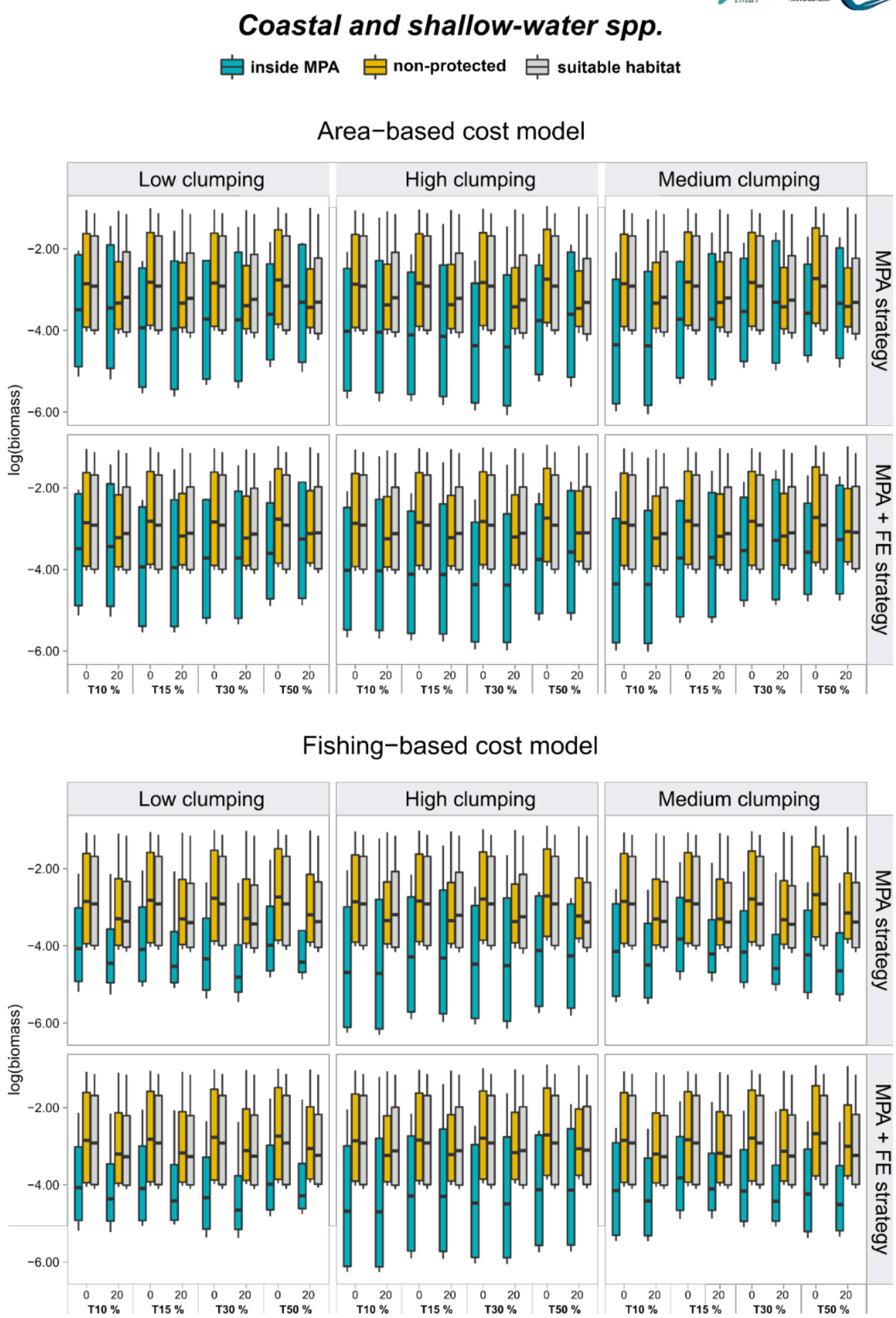


Figure 73. Projected reserve effect measured as the absolute suitable biomass ($t \cdot km^{-2}$, log scale) of benthic coastal and shallow-water fish groups combined, estimated within the different conservation planning scenarios developed for the Azores deep-sea ecosystems and adjacent non-protected grounds, before (year 0) and after (year 20) the simulated implementation. These scenarios considered a) four different spatial planning area targets (10%, 15%, 30%, and 50%), b) three different configurations of priority areas for management and conservation design (high, low and medium clumping), c) two cost models (fishing cost, and area-based cost), and d) two management strategies that considered alternative levels of fishing effort.

8.3 Influence of network design on the ecosystem and fisheries projections

Model projections suggested no major effects of the network configuration design (clumping) in the biomass change of both deep-sea fish and coastal and shallow water fish species (Figure 74). Although this results may have to be interpreted with caution, they point to the fact that spatial planning targets and cost models to be main drivers of the differences observed in the biomass change. The role that size plays on the magnitude of reserve effects remains contentious. Some authors argue that the impact of marine reserves is independent of reserve size (Halpern 2003; Guidetti & Sala 2007), while others suggest that reserve effects are size-dependent (Claudet et al., 2008). Our modelling-based results support that "reserve effects", within the boundaries of the MPA network and on commercially important benthic fish groups, were predominantly independent of the size. Yet, network size revealed to be important in building-up the biomass of top-predators, leading to more intense trophic cascade effects within the reserve, as the size of the network increased.

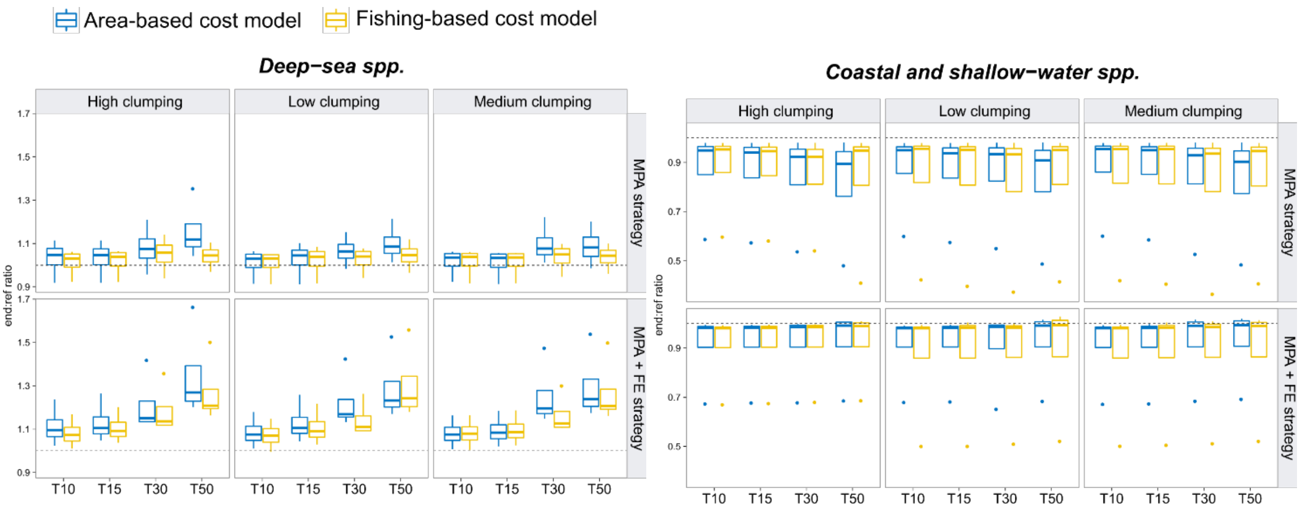


Figure 74. Relative changes in the biomass of deep-sea and coastal and shallow-water species forecasted after 20 years of Ecospace simulations for multiple scenarios of fishing restrictions under the MPA and MPA+FE strategies and different configurations (low, medium and high clumping). T10%, T15%, T30%, and T50% corresponded, respectively, to 13%, 16%, 23%, 33% averaged reductions in fishing effort modelled in scenarios under the MPA+FE strategy.

8.3.1 Overall ecosystem and fisheries projections (15% spatial planning target)

Our model projections showed no major differences in the ecosystem and fisheries outcomes among different configurations of priority areas design and cost models (Figure 75, Figure 76). However, the Ecospace model projected higher biomass increases of benthic fish species with high and low clumping designs (Figure 75). It is difficult to explain why medium clumping designed networks were projected to produce smaller positive effects in the biomass of most fish groups (Figure 75) but greatest catches over time (Figure 76). Projections did not indicate pronounced differences among the cost-models, although the biomass of most benthic fish species were projected to increase the most under area-based scenarios, while fisheries yields were projected to decrease the least under the fisheries cost model. Thus, results support that the protection of highly valued areas does not carry out greater costs for fisheries.

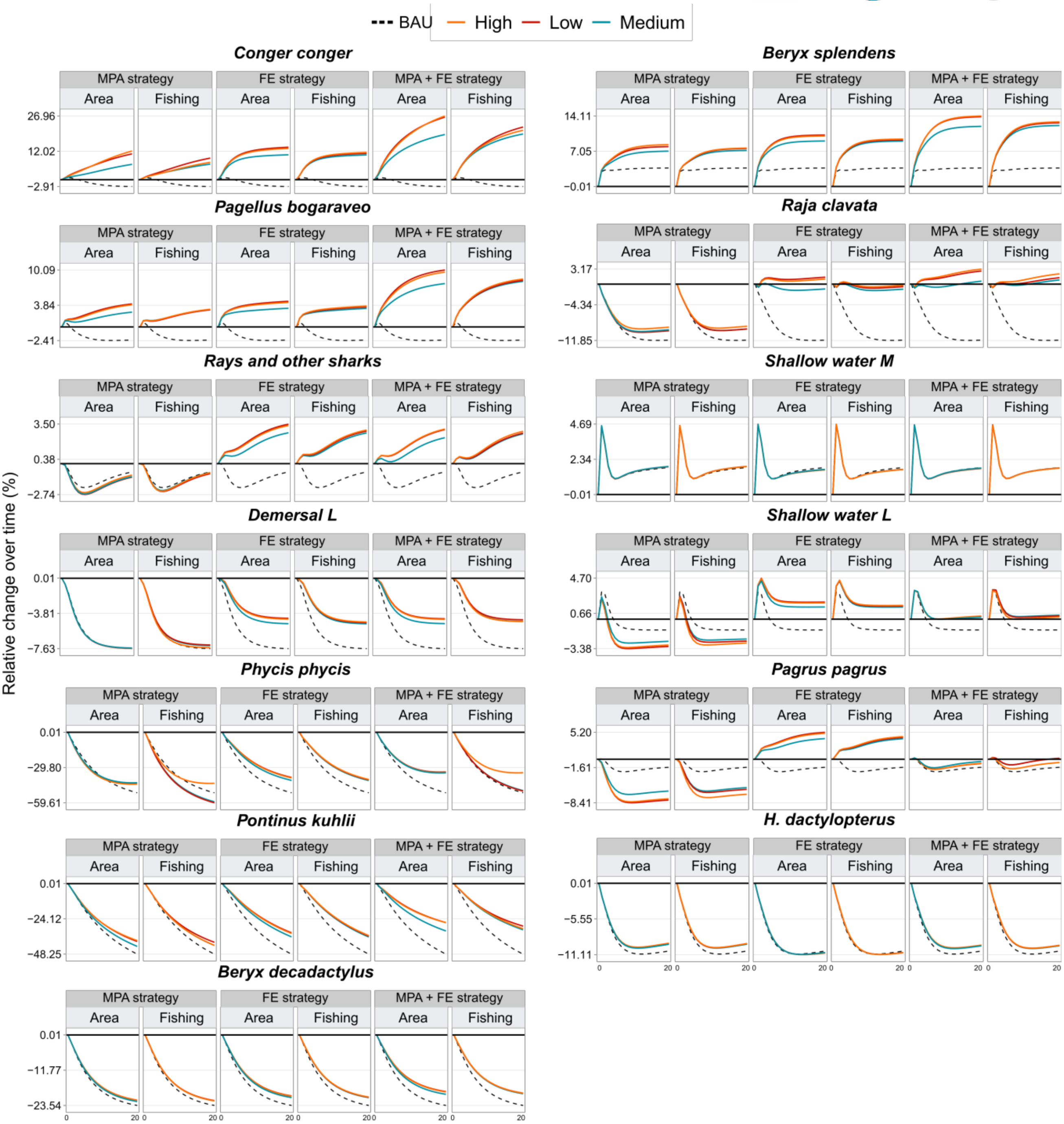


Figure 75. Relative changes in the biomass of commercially important fish groups forecasted with Ecospace simulations for scenarios targeting 15% of fishing closure, under the *MPA, FE,* and *MPA+FE* management strategy scenarios, and two cost model (area-based and fisheries based). In the x-axis, 0 corresponds to first year of simulation and 20 to the maximum year simulated.

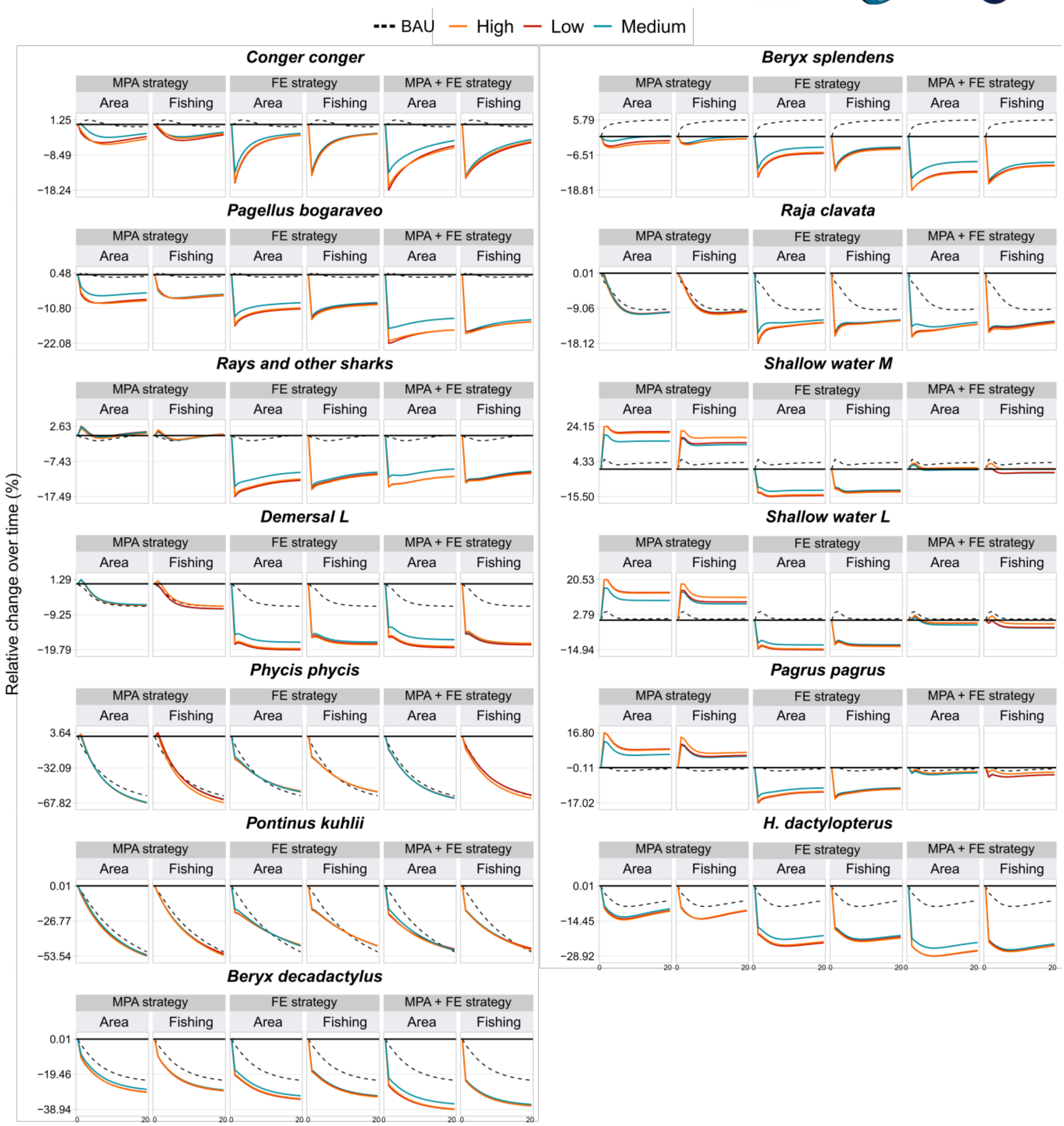


Figure 76. Relative changes in the catch of commercially important fish groups forecasted with Ecospace simulations for scenarios targeting 15% of fishing closure, under the *MPA, FE,* and *MPA+FE* management strategy scenarios, and two cost model (area-based and fisheries based). In the x-axis, 0 corresponds to first year of simulation and 20 to the maximum year simulated.

8.3.2 *Projection of spatial displacement of fishing effort and biomass of benthic species (15% spatial planning target)*

The relative change (end/start, %) in the spatial distribution of fishing effort and biomass of deep and shallow water benthic groups for the scenarios targeting 15% closure and using medium clumping is shown in Figure 77. Our model projections suggest mostly small spatial changes in the distribuiton of fishing effort under the BAU scenario. Fishing effort was predicted to concentrate in shallow water seamounts (Princesa Alice in particular) and around all islands shelfs. The biomass of deep-water benthic fish species was projected to decrease in most fishing grounds with the exception of the isand slopes of Flores, Corvo and São Jorge. The biomass of shallow-water groups was predicted to decrease in most of the EEZ, while minor (<1.4%) increases were suggested in the east side of São Jorge and of Terceira island (Maçarico seamount).

Significant changes in the spatial distribution patterns were projected after the implementation of the network of closed areas MPAs when compared to BAU, but no major changes were projected among the Area-based and Fisheries-based cost models (Table 28). Namely, the spatial distribution of fishing effort, regardeless of the cost-models (Kfuzzy = -0.08), was predicted to be displaced out of the closed areas and increased in most fishing grounds (Figure 77). This increase in fishing effort in most fishing grounds is projected to produce significant reductions in the biomass of deep-water benthic fish species; but a significant increase inside closed areas suitable for these species (Voador and Cavala seamounts; Figure 77). It is noteworthy that areas where effort / biomass was overall low in the past, highlight the greatest changes upon the implementation of MPAs (Hard Rock Café and Isolado seamounts). The biomass of shallow-water species was predicted to decrease the most on off-shore non-protected seamounts (e.g., Princesa Alice) and increase inside the protected grounds of Mar da Prata, Voador and Cavala. The greatest mismacthes in spatial distribuition patterns, between cost-models, were actually predicted for shallow-water biomass of benthic fish (Kfuzzy=0.38; Table 28). Those differences were significant in the north of São Miguel Island, Maçarico seamount, west of Terceira island, Açor bank (south of Pico), and off-shore seamounts (e.g., Princesa Alice, Monte Alto).

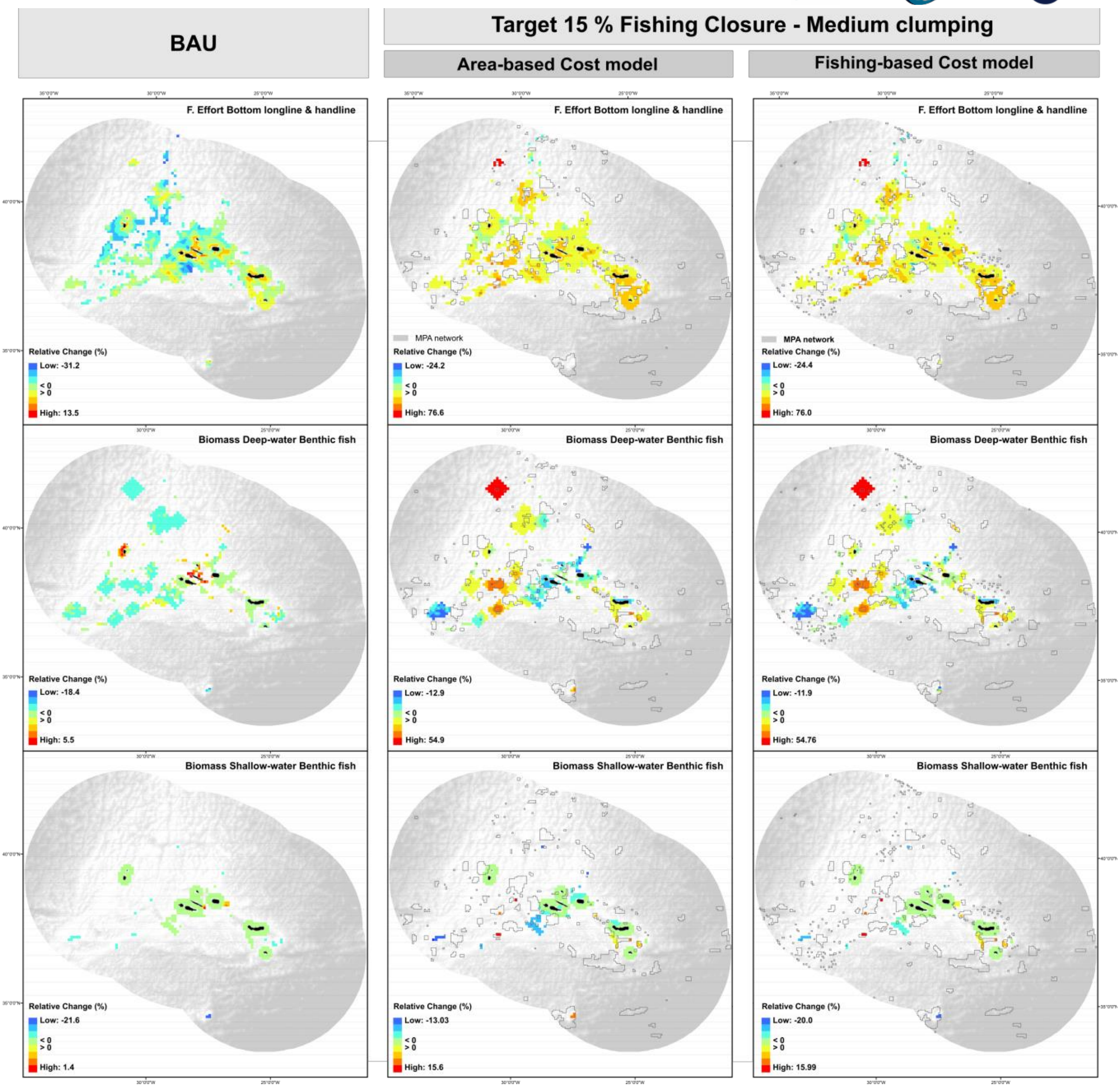


Figure 77. Changes in the spatial distribution patterns of fishing effort and biomass of deep and shallow-water benthic fish functional groups, predicted with Ecospace under the BAU scenario (left) and the MPA scenario targeting 15% of fishing closure. Area-based and fishing-based cost models, respectively represented in the central and right panels.

Table 28. Summary table of spatial agreement between the maps of analysed scenarios, based on the Fuzzy Kappa index (Hagen-Zanker, 2009). The gradient of colour corresponds to the strength of agreement (red - poor; dark yellow - slight; light yellow - fair; green - almost perfect; Landis & Koch, 1977).

Scenarios	Fishing Effort	Deep-water Biomass	Shallow-water Biomass
BAU vs Fishing-based Cost Model	-0.08	0.04	0.29
BAU vs Area-based Cost Model	-0.08	-0.06	0.07
Fishing-based Cost vs Area-based Cost	0.95	0.87	0.38

8.4 Summary ecosystem and fisheries projections

The Azores Ecospace model comes with several caveats and uncertainties (Section 5.8.4) but has been demonstrated useful to project the ecosystem and fisheries impacts of several spatial management scenarios. It should be stressed that the Azores Ecospace model is a deep-sea benthic fish-centred model, designed to explore deep-sea fisheries management regulations. Therefore, it is not the most appropriated model to address impacts in the pelagic environment. Nonetheless, the current version of the spatial model was not designed to address the impacts of fishing on Vulnerable Marine Ecosystems and therefore no conclusions in this regard should be taken. Given the characteristics of the modelling approach, model design and data availability for model calibration and validation, the current model is better suited to address SCP goals and objectives that focused on rebuilding fish stocks of commercially important deep-sea benthic species.

The results of this study highlighted that networks of MPAs in the Azores can have strong positive effects in the biomass of top-predators*,* and lead to spatial trophic cascade effects through the food-web. However, significant reshapes in the structure and functioning of the ecosystem were restricted within the reserve. Here, we summarize the main ecosystem and fisheries projections obtained by using a spatial ecosystem modelling approach.

Projections under a Business as Usual Scenario projected future depletion of most commercial fishes

One of the first conclusions of the ecosystem and fisheries projections was that under a Business as Usual Scenario assuming *status quo* levels of fishing effort and environmental conditions similar to those observed in recent years, the biomass and consequently catch of the largest majority of exploited benthic fish species were predicted to decrease over the coming years. This projection is in agreement with the recent evidences and anecdotal perceptions that some fish stocks in the Azores are being exploited above sustainable limits (Morato et al., 2012; ICES, 2017; 2019; Santos et al., 2019b). This first conclusion supports the necessity of additional management measures that could halt or invert the decreasing trend.

The positive impacts of "no-take areas" are greater when fishing stocks are highly depleted

The Azores Ecospace model projected that the implementation of all management strategies would have positive impacts in the overall biomass of benthic fish species but negative impacts in their catch. Particularly for those scenarios considering a reduction in fishing effort proportional to the fishing effort lost within the MPA network. The overall limited projected performance of MPA networks in delivering fisheries gains reflects that positive net effects of marine reserves on fishery spillover are more likely to be detected when fishing stocks are highly depleted (Buxton et al., 2014, Le Quesne & Codling, 2009). In these cases, achieving both conservation and fisheries objectives through the implementation of a network of marine protected areas may be particularly challenging.

This aspect raises two questions: are Azores fisheries stocks not highly depleted? Or is the modelling approach not capturing local baseline conditions? We argue that both points might be valid. As mentioned above, there are evidences that some fish stocks are being overexploited, but not to levels that are perceived to generate great risks to fishing stocks (ICES, 2017; 2019). At the same time, the baseline Ecopath model underestimated the fishing mortality rate for most of the exploited benthic groups, including *P. bogaraveo* when compared to those published by Pinho et al. (2015). Since the model predicts past and current harvesting is bellow biological reference levels (i.e., F<M0), fishing restrictions will have a direct negative impact in fisheries yields, as most

of the fish stocks was predicted to not be recovering from overexploitation. We believe that the pitfall of the model underestimating the exploitation condition of the ecosystem underpins the low magnitude of “reserve effects” on deep-sea fish biomass, relatively to non-protected grounds, in comparison to values reported elsewhere.

The implementation of “no-take areas” in the deep-sea may require longer time-frames

Our model projections suggested that the “reserve effect”, although well noticeable, was smaller than what has been typical reported for shallow-water and coastal environments (Halpern, 2003; Cheng et al., 2019). The projected smaller increase when compared to other studies might be related to the fact that most deep-sea species will take longer to recover due to their life-history characteristics (Devine et al., 2006; Marschoff et al., 2012). However, the smaller reserve effect could also be related with the baseline information used in the model that considered most deep-sea species not to be depleted, and therefore response to management measures are more difficult to observe (see above). Additionally, due to the complex topography of the Azores EEZ, the spillover effects to neighbouring cells might be limited in off-shore and deep-water grounds, as the adjacent areas might not be suitable habitats and therefore lead to weak spillover effects (Freeman et al., 2009). This may also contribute to the observed reduced reserve effect within the time-frame projected in this study. Consequently, the implementation of “no-take areas” in the deep-sea may require longer time-frames when compared to those in shallow-water environments, as already observed in other areas (Sackett et al., 2014). Closed areas that safeguard connectivity to suitable habitats (e.g. seamounts, island slopes) might reduce the time-frames required for recovery of deep-sea environments and be more appropriated to sustain fisheries catches (Tupper, 2007).

The implementation of “no-take areas” should be accompanied by other fisheries management measures

We noted that the implementation of a MPA strategy projected potential detrimental effects in some shallow-water and coastal commercially important fisheries stocks. This may result from the displacement of fishing effort to coastal and shallower fishing grounds, with potentially negative effects on fish stocks of *Phycis phycis, Pagrus pagrus* and the large-size shallow water fish group (representative species, *Serranus atricauda*). This aspect highlights the need for specific prioritization approaches for the coastal areas and coastal and shallow water biodiversity. Notwithstanding, following the MPA implementation with additional fisheries tools (i.e., effort reductions) might be crucial to avoid local depletion of stocks in response to the displacement of fishing activities to non-protected grounds. These results are in line with Hilborn et al. (2004), suggesting that no-take areas should be accompanied by other fisheries management tools (i.e., catch or effort limits) in order to avoiding negative effects in the stocks and achieve conservation and ecosystem-based management goals. However, it is noteworthy that rebuilding fish stocks should not be considered the only management goal to be achieved and that the MPA strategy have additional positive outcomes (e.g. protection of VMEs) not measured with this approach.

9. Representativity approach based on simplified prioritization solutions

Since the scientific information was considered to be inadequate or insufficient to justify a full data-driven approach in the "data-poor abyssal", we have complemented the prioritization approach with a new representativity approach design to identify representative areas of all seabed habitats, to ensure connectivity across the entire spatial planning area, and to achieve the prioritization targets.

9.1 Simplified outputs based on the aggregated prioritization solutions

9.1.1 Aggregation of the prioritization solutions

The outputs from the twenty-four scenarios were combined to display the relative importance of areas to fulfil the overarching goals and objectives. However, since the two different cost models used (area-based cost *vs* varying fishing cost) were designed to address different goals (protect important but less impacted areas to reduce the socio-economic cost *vs* to restore important but potentially impacted areas regardless of the cost), the twelve scenarios with the area-based cost and the twelve scenarios with the fisheries-based cost were treated separately. For these two groups, the binary outputs were summed to display the selection frequency of PUs across the twelve considered scenarios. Hence, frequency value was low for the areas that were rarely selected, and high for the areas that were frequently or always selected. The important areas always had the highest value since they were locked in the solutions (i.e., always selected). Creating these two summed outputs (Figure 78) allowed to identify, along with this locked-in network, the other areas that revealed their importance across the different sets of targets and network clumping. The main goal of the summed outputs was thus to highlight the areas of high conservation priority for the deep-sea of the Azores EEZ.

The aggregation of the prioritization solutions for the 12 area-based cost and 12 fisheries-based cost scenarios (Figure 78) showed that most of the differences in the prioritization solutions between the two cost models were located in the central and north Mid Atlantic Ridge. It should be noted that the locked-in areas always achieve the maximum aggregated value since they were compulsorily included in all the solutions.

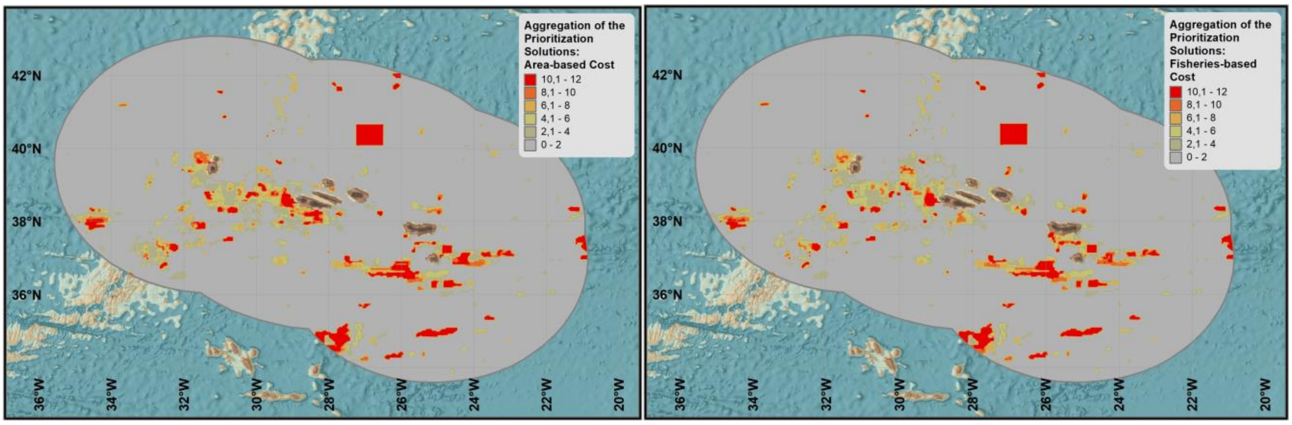


Figure 78. Aggregation of the prioritization solutions for the area-based cost (left) and fisheries-based cost (right). Scenarios considering the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores. The colour scale represents the number of times PUs were selected across the 12 scenarios, from 0 (grey) for the PUs that were never selected, to 12 (red) for the PUs that were either locked-in the solutions or always selected in the prioritization approach.

9.1.2 *Simplified prioritization solutions*

Simplified versions of the prioritization outputs were built based on the aggregation of the prioritization solutions and the aggregated value for each PU. These simplified outputs, synthesised the results of the three different configurations (high, medium, and low clumping) for each of the four spatial planning closure targets. The aggregation of the prioritization solutions were converted into discrete priority areas for management conservation based on the number of times each cell was selected in the aggregation results (Figure 79). Each cell was considered as an important area if selected at least in 8 times in "data-rich" and 4 times in "data-poor abyssal" prioritization solutions.

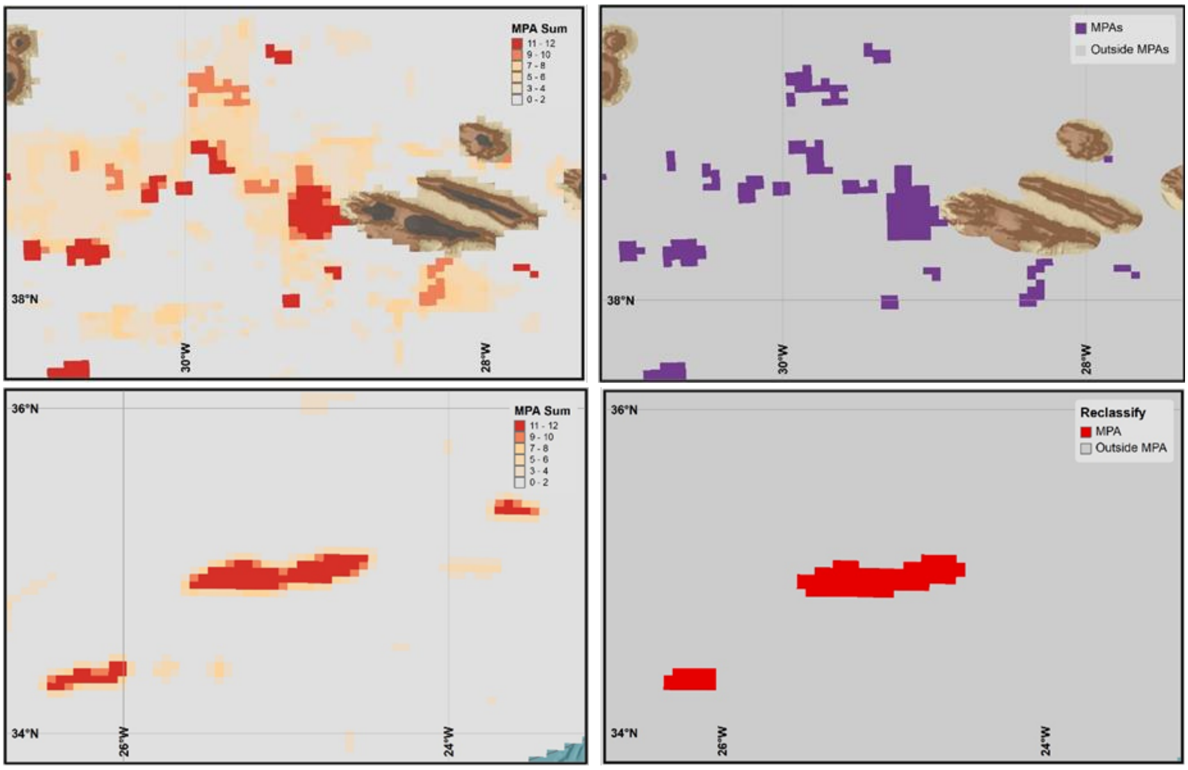


Figure 79. Reclassification of the aggregation prioritization solutions into discrete priority areas based on the number of times each cell was selected in the aggregation results (8 in the "data-rich" and 4 in the "data-poor abyssal" areas).

The discrete priority areas may result in unmanageable number of areas some with complex shapes which are usually difficult to transfer into management regulations (e.g. Norse et al., 2010). We have, therefore, adopted an approach to reduce the number of discrete priority areas using a set of spatially-explicit rules based on their dimension and distance to closest neighbour. A small area was defined as those discrete priority areas with 4 or less PUs (i.e. <100km^2) in the "data-rich" area and 30 or less PUs (<750km^2) in the "data-poor abyssal" area. The minimum distance to closest area is 5km (average 36.4km) and 12.9 (average 77.1km) km in the "data-rich" and "data-poor abyssal" areas, respectively. Close areas were considered as those areas geodesic closer than 5km (<2 PUs) or 15km (<4 PUs) in the "data-rich" and "data-poor abyssal" areas, respectively. Following these thresholds, we applied two rules: 1) small areas but close to larger areas were merged; and 2) small but isolated areas were increased in size to 4 PUs (100km^2). No discrete priority areas were discarded.

We have addressed the problem of resulting complex shapes by simplifying the boundaries of the discrete priority areas using the Minimum Bounding Geometry tool in ARCGIS v10.6. We applied the Convex Hull geometry (irregular outputs) to redraw the smallest polygon enclosing each discrete priority area in the "data-rich" area the Envelope geometry (rectangular outputs) in the "data-poor" area (Figure 80). The Envelope geometry was not applied in the "data-rich" area because of the proximity between the discrete priority areas.

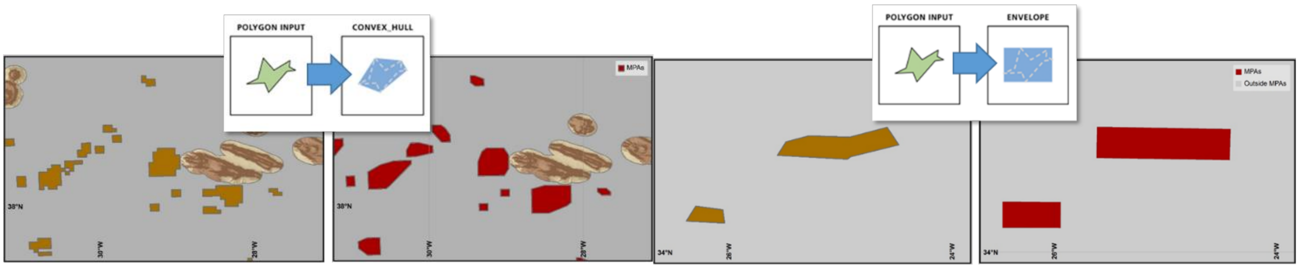


Figure 80. Simplifying the boundaries of the discrete priority areas using the Minimum Bounding Geometry tool. Differences produced by the use of the Convex Hull geometry (irregular outputs; left) and the Envelope geometry (rectangular outputs; right).

9.1.3 Existing network of marine protected areas

The existing network of MPAs in the Azores was not included in the spatial prioritization approach to avoid constraining the selection of priority areas. See section 5.2.1 for details. However, in the simplification of the priority areas approach we did took those areas into account by merging the existing MPAs not considered in the prioritization solutions with the network of simplified priority areas (Figure 81).

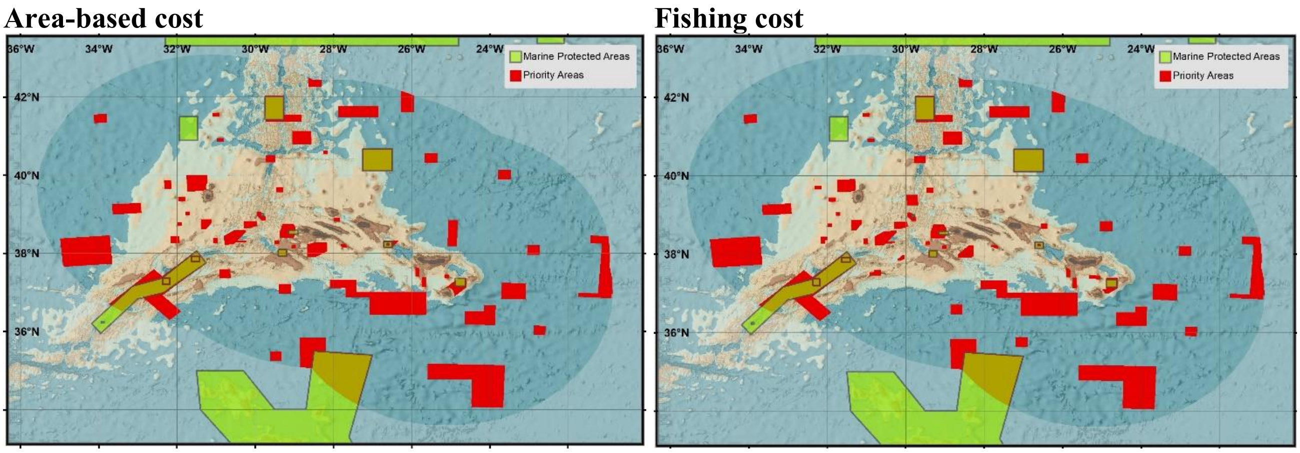


Figure 81. Overlaying the network of simplified priority areas with the existing network of marine protected areas in the Azores for the area-based cost scenarios (left) and the fisheries-based cost scenarios (right).

9.2 Complementing the network with a representativity and connectivity approach

The debate on the importance of considering connectivity in conservation planning and in the design of networks of protected area is still ongoing (Section 5.2.2). However, here we followed the scientific evidence that suggests the benefit of combining representativity and connectivity objectives to enhance success of the network of marine reserves (Berling et al., 2012; Balbar & Metaxas; 2019; Manel et al., 2019). To achieve the prioritization targets (spatial planning closure and the feature's representation targets) in the "data-poor abyssal" area and to ensure connectivity across the entire spatial planning area, we have complemented the prioritization approach with a new representativity and connectivity approach design to increase connectivity between priority areas and identify representative areas of all seabed habitats.

9.2.1 *Topological cost connectivity framework*

In order improve the representativity and connectivity of the network of simplified priority areas we have used a topological cost connectivity framework with the goal of defining the optimum network of least-cost paths. This topological connectivity analysis is usually performed by social network's experts to assess the centrality of a given community (Heer & Boyd, 2005; Behrisch, 2018). It should be noted that this process involves a great deal of expert-judgement. In this analyses we aimed to identify those paths or corridors that may allow marine biodiversity to move between patches of protected areas that may contain suitable habitats. This approach follows various steps: 1) identify the network of simplified priority areas; 2) compute cost surface that identifies the cost of traveling through each PU, often used to represent several criteria; 3) compute a cost-distance surface that identifies the cost of traveling over a surface (spatial planning area); and 4) compute the cost connectivity that identifies the least-cost paths from each priority area to its neighbour priority area.

This process was firstly run to identify the least connected priority areas to inform the design of new priority areas or to redefine limits of the simplified priority areas. Here we used the network of simplified priority areas and computed cost surface (Figure 82) based on the aggregation of the prioritization solutions (higher cost in less selected PUs), the bathymetry of the spatial planning area (higher cost in deeper PUs), and the location in the sub-areas (higher cost in the "data-poor abyssal" area). The resulting cost-distance surface was used to compute the cost connectivity network that revealed higher cost paths and reduced representativity in the abyssal plains (Figure 82).

Cost surface identifies the cost of traveling through each PU | **Cost-distance surface identifies the cost of traveling over the surface** | **Cost connectivity identifies the least-cost path between neighbours**

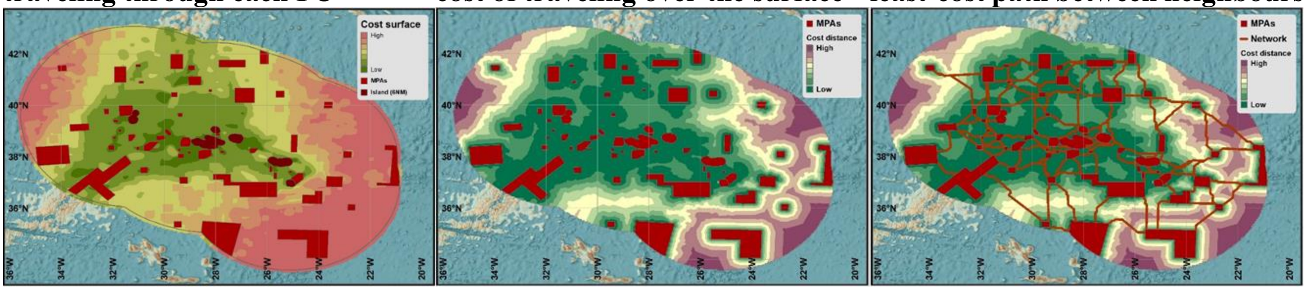


Figure 82. Topological cost connectivity framework showing the cost surface, cost-distance surface and the cost connectivity of the network of simplified priority areas designed for the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores. The example shown here is for the simplified network built with the area-based cost model.

Following the topological cost connectivity analyses, we proposed additional priority areas to increase the representativity of the abyssal plain and reduce the cost of the connectivity network. For this, we computed a new cost layer based on the Flat area seabed habitat (lower cost in PU with Flat areas) and identified those areas in the abyssal plain less represented in the network (Figure 83). Then, we created 8 and 9 new priority areas for the area-based and fisheries-based cost scenarios, respectively, and expanded three existing priority area in both scenarios (Figure 83). The new areas were created in the abyssal plains of both the Eastern and Western "data-poor abyssal" areas. The topological connectivity analysis was run a second time is to evaluate if the improved design increases the representativity and connectivity of the network (Figure 84).

Area-based cost **Varying fishing-based cost**

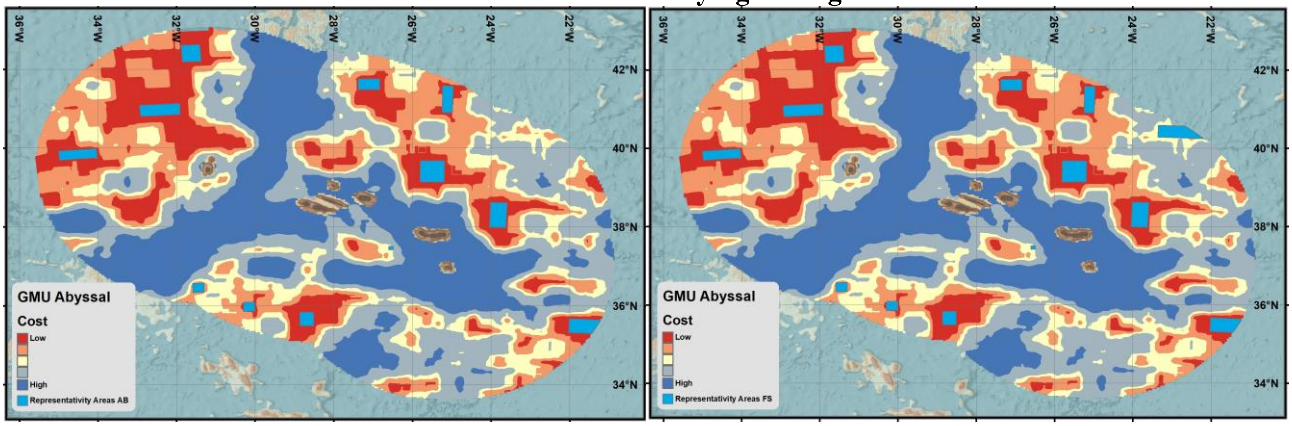


Figure 83. Seabed habitat cost surface based on the flat area seabed habitat (lower cost in PU with Flat areas) and identified those areas in the abyssal plain less represented in the network. This was computed on the simplified priority area network built with the area-based and fisheries-based cost scenarios.

Cost-distance surface **Cost connectivity network**

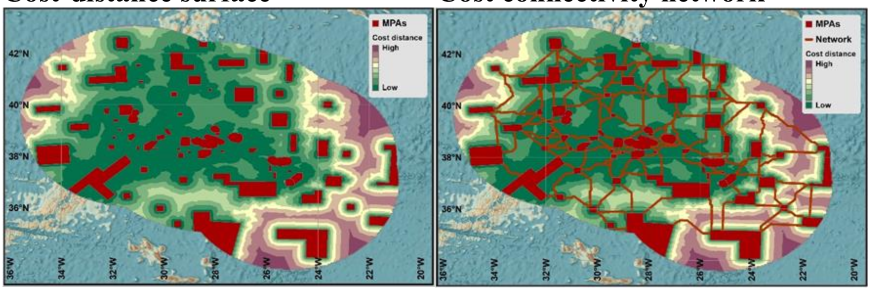


Figure 84. Topological cost connectivity framework showing the seabed habitat cost surface, cost-distance surface and the cost connectivity of the network of simplified priority areas. The example shown here is for the simplified network built with the area-based cost model.

The cost of the connectivity network revealed reduced cost paths and improved representativity in the abyssal plains. However, we identified a specific area west of São Miguel Island where the connectivity cost was still considerable and no paths crossing this areas were identified. As a result, a new priority area was suggest that reduces considerably the connectivity cost around this area (Figure 85). Two areas new priority area were suggest in the fisheries/based cost scenarios.

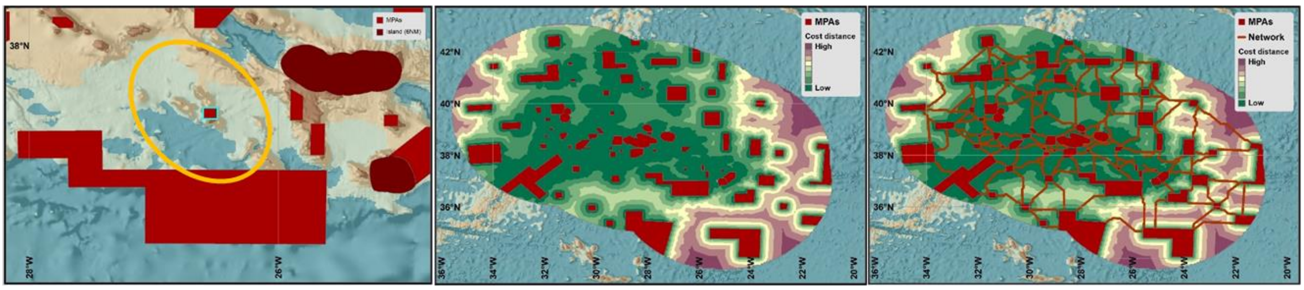


Figure 85. Specific location in the "Data-rich" area with high connectivity cost and with no paths crossing this areas that originated the suggestion of a new priority area (right). The final topological cost connectivity framework showing the cost-distance surface and the cost connectivity of the network of simplified priority areas is also shown. The example shown here is for the simplified network built with the area-based cost model.

9.2.2 Assessing the connectivity of the final network

Finally, we develop a scoring system based on the network analysis to assess the connectivity of the final simplified versions of the network of priority areas. For this purpose, we applied the network centrality metrics to identify the importance of the different elements in the network (Brandes, 2005; Butts, 2009), namely the reachability indicators (Koschützki et al., 2005; Bloch et al., 2019) which are used to find the ability of nodes to reach the closest nodes:

- Reachability with net links; number of shortest paths from source (starting node) to sinks (end node). Higher values indicate the higher importance of the nodes in the network;
- Reachability with sum length; the number of shortest paths with a sum of distance-links (under the cost distance model). Higher values indicate the higher importance of the nodes based on the sum of distance-links.

The maps with the reachability indicators illustrate the centrality of the different priority areas in the whole spatial planning area (i.e. the EEZ around the Azores). This analyses highlight the importance of the peripheral areas in connecting the whole network both in terms of net links and sum lengths (Figure 86). This framework can be replicated during the discussion processes.

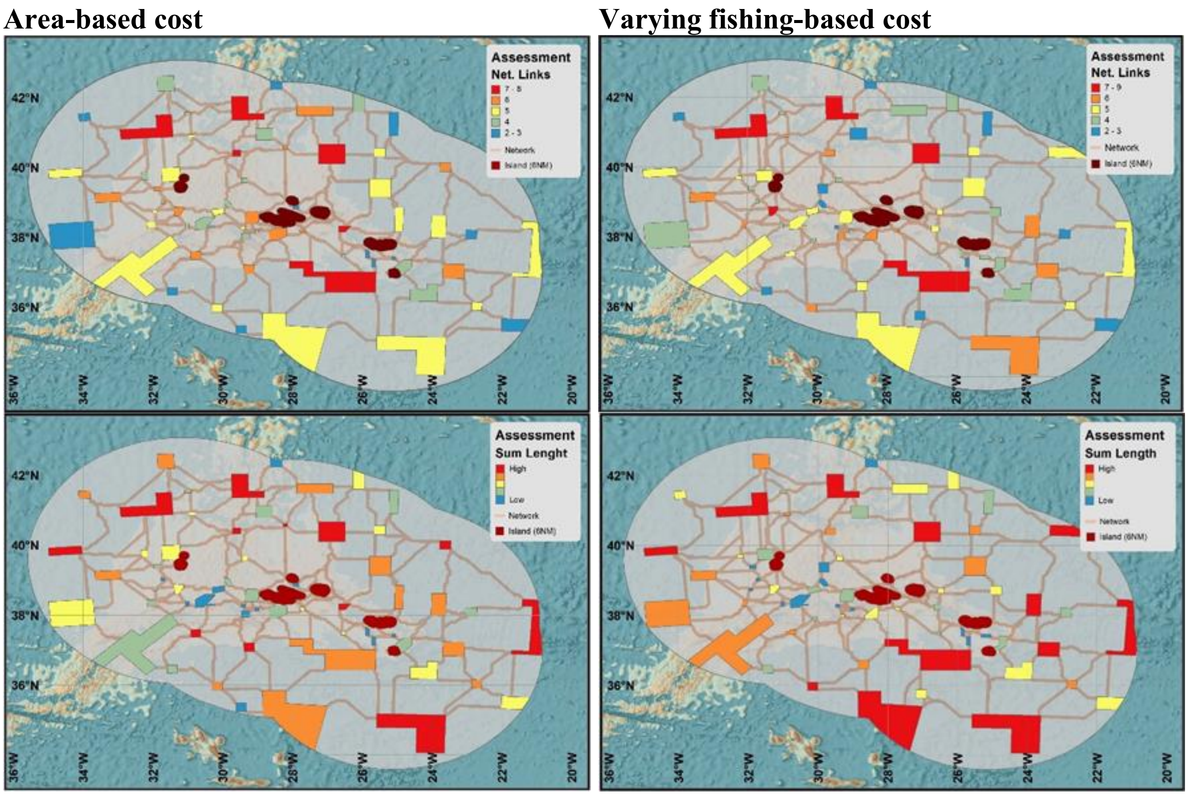


Figure 86. Reachability indicators used to identify the importance of the different elements in the final simplified network of priority areas, namely the reachability with network links (top) and reachability with sum lengths (bottom). Reachability indicators were calculated for the area-based cost scenarios (left) and the fisheries-based cost scenarios (right).

9.3 Simplified and complemented network of priority areas

In summary, the simplification of the systematic conservation planning scenarios developed to address the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores resulted in 62 and 63 priority areas for management and conservation for the area-based cost (Figure 87) and varying fisheries-based cost (Figure 88) models, respectively. The networks resulting from this complex approach is composed of:

- 21 Important Areas that based on current best available knowledge (data-driven approach) are features of particular ecologically or biologically importance and the most suitable to achieve the planning goals (Section 5.1). These areas were always included in the solutions (a.k.a. locked-in areas);
- 30 and 29 areas for the area-based and fisheries-based cost models, respectively, resulting from the prioritization approach. These areas complement the Important Areas with areas that based on current best available knowledge (data-driven approach) contain important resources and also consider the existing network of Marine Protected Areas;
- 11 and 14 areas for the area-based and fisheries-based cost models, respectively, resulting from the complementary approach to increase the representativity and connectivity of the networks.

The resulting networks contain 57 areas that appeared in both the area-based and the varying fisheries-based cost models, 5 that appeared only in the area-based and 6 only in the fisheries-based cost.

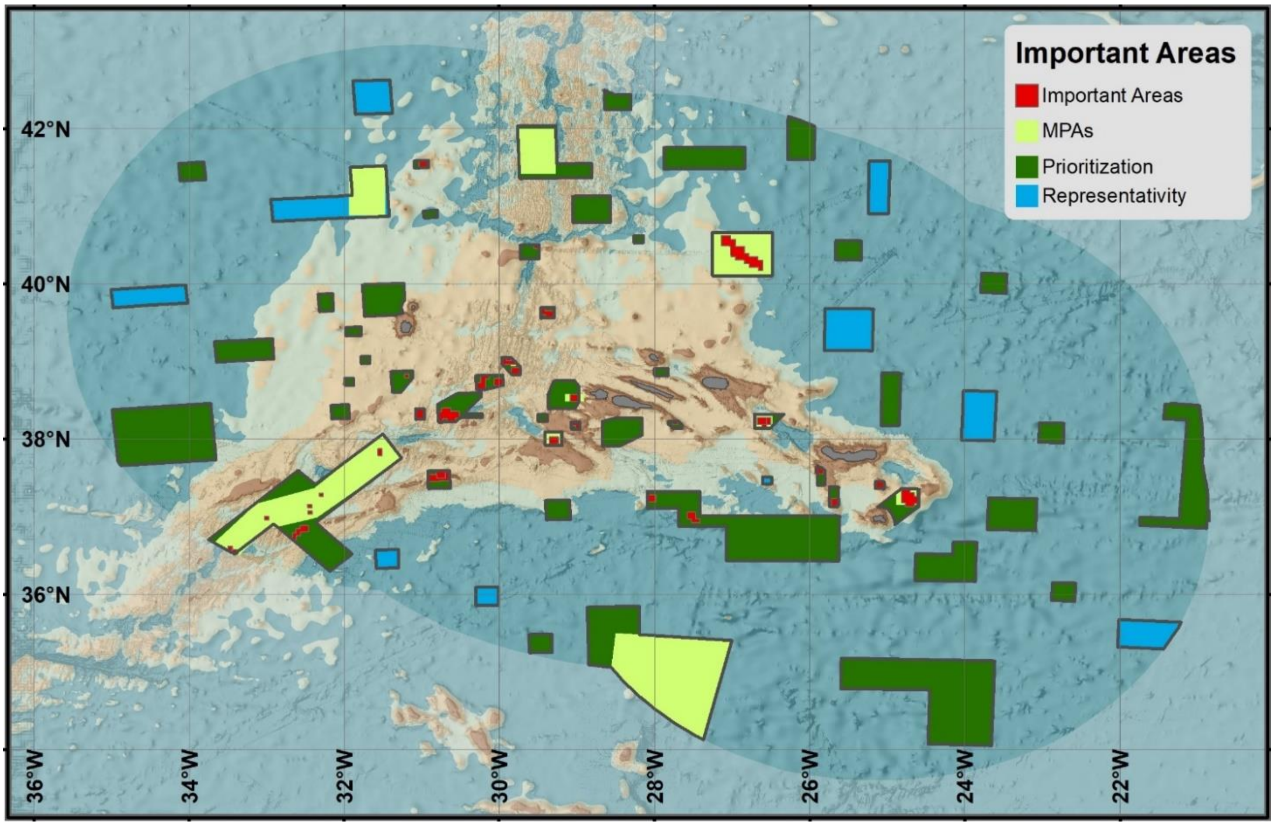


Figure 87. Simplification of the systematic conservation planning scenarios developed to address the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores resulted in 62 priority areas for management and conservation for the ***area-based cost***. The network resulting from this complex approach is composed of 19 Important Areas 32 areas resulting from the prioritization approach, and 11 areas resulting from the complementary approach to increase the representativity and connectivity of the networks.

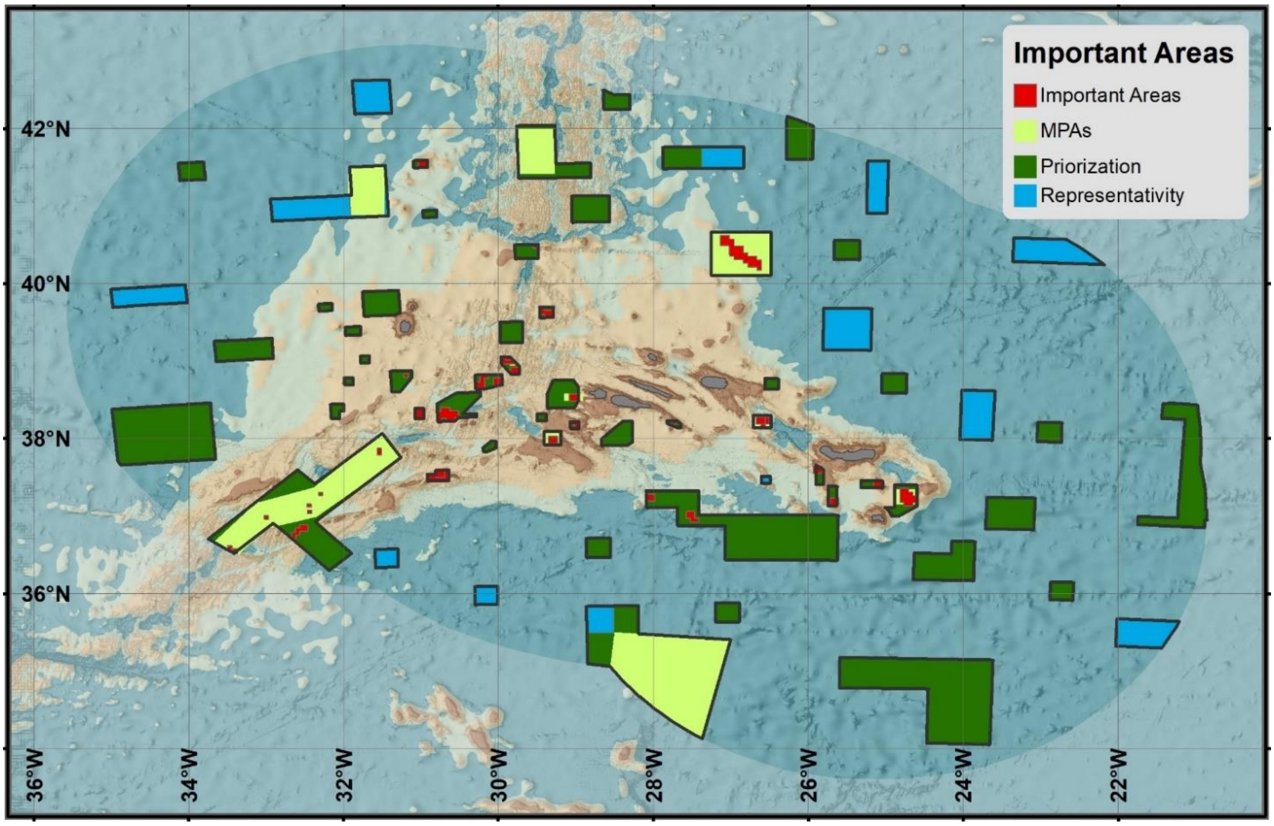


Figure 88. Simplification of the systematic conservation planning scenarios developed to address the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores resulted in 63 priority areas for management and conservation for the ***varying fisheries-based cost***. The network resulting from this complex approach is composed of 19 Important Areas 30 areas resulting from the prioritization approach, and 14 areas resulting from the complementary approach to increase the representativity and connectivity of the networks.

The network of priority areas is spread throughout the whole EEZ (i.e. spatial planning area) both in the "data-rich" and in the "data-poor abyssal" (Figure 89). The network covers an areas of about 133km^2, but only about 4% is used by the local bottom fishing industry with different degrees of fishing effort (Figure 89). However, the network overlaps with 25% to 28% of the bottom longline fishing effort as measured with the analyses of VMS data (Figure 89).

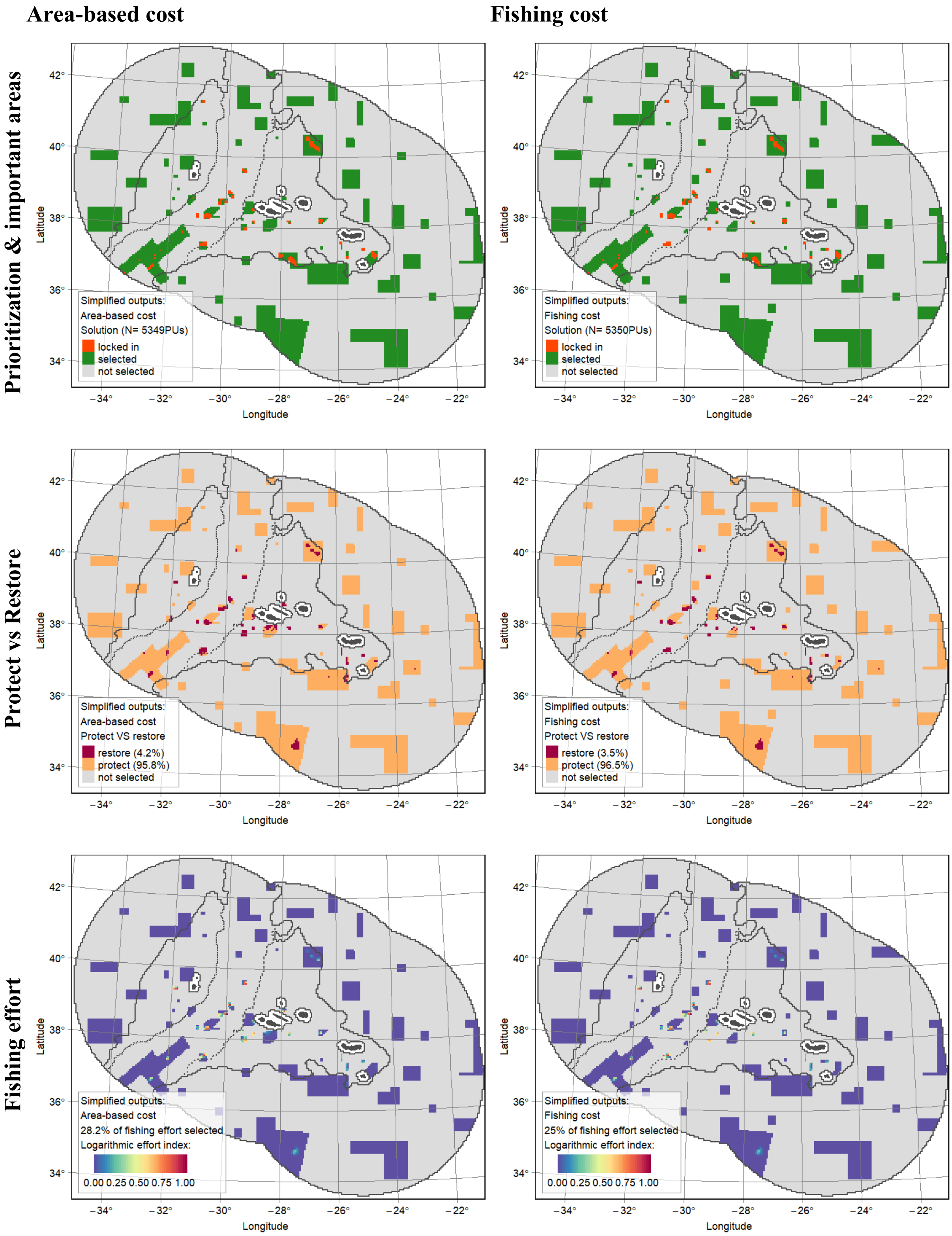


Figure 89. Simplified and complemented network of priority areas.

9.4 Brief performance assessment of the simplified network

9.4.1 Deep-sea benthic environments

The performance assessment of the simplified network of priority areas that resulted from complementing the prioritization network with a representativity and connectivity approach, increased significantly. It should be noted that no major differences were noted between the performance of the area-based and fisheries-based cost models.

The size of the simplified and complemented network now reaches about 133km^2, which represents about 14.2% of the spatial planning area (Table 29); approximately 12% of the "Data-rich" area and 15% of the "Data-poor abyssal" area. It means that the 15% target was achieved in the "Data-poor abyssal" area. As a result of the whole simplification process, the total number of individual priority areas in the simplified and complemented network was significantly reduced while the average size was significantly increased to about 2,100km^2 (Table 29). This aspect reflect the desire of achieving a manageable number of priority areas for management and conservation. The connectivity of the network of simplified priority areas was also significantly increased (Table 29). It should be highlighted that the proportion of fishing footprint included in the simplified networks didn't change much when compared to the results of the prioritization approach only (approx. 23% and 19% for the area-based and fisheries-based cost models, respectively). This reflects the fact that a large portion of the fishing footprint occurs in the important areas that were always considered in the solutions. It should be, however, highlighted that the fisheries-based cost model was able to slightly reduce the fishing footprint included in the simplified and complemented network of priority areas. In general, the spatial overlap with the local Azores the bottom longline fleet was most evident in some seamounts along the MAR and in the Princesa Alice bank (Figure 90).

The proportion of isolated priority areas (dist. >100km) and the proportion of the network area that is isolated was reduced to about 1%. The maximum distance to the closest neighbor was also reduced to approx. 140km suggesting that most areas might be within reachable distances for most deep-sea fauna. However, because of the reduced number of individual priority areas in the simplified solution the proportion of highly connected areas (* ≥10 neighbours and max. distance to closest neighbour ≤ 100km) and the proportion of the network area that is highly connected decreased significantly.

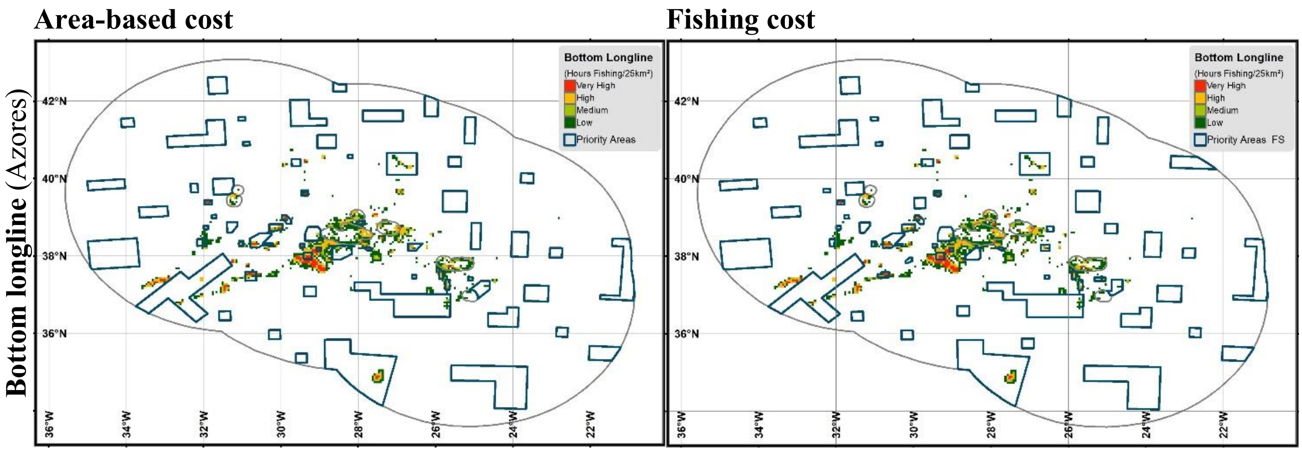


Figure 90. Overlaying the network of simplified priority areas with estimates of fishing effort for bottom contact gears produced with an analyses of the VMS data in the Azores for the area-based cost scenarios (left) and the fisheries-based cost scenarios (right).

Table 29. Performance assessment of the "viability and adequacy", "replication" and "connectivity" design criteria for simplified network of priority areas developed for deep Azores ecosystems. These scenarios considered a) one spatial planning area targets (15%), 2) one configurations of priority areas for management and conservation design (medium clumping), and c) two cost models (fishing cost, and area-based cost).

Spatial planning area targets	15%	
Cost	AB	FB
Clumping	Med.	
Viability and adequacy		
Size of the network (x1000 km^2)	133.7	133.2
% Spatial planning area	14.2	14.2
% "Data-rich" area	12.7	12.1
% "Data-poor abyssal" area	14.9	15.2
% Spatial closure target achieved	94.5	94.5
% "Data-rich" spatial target achieved	84.9	80.9
% "Data-poor abyssal" target achieved	99.3	101.4
% Priority areas in "data-poor abyssal"	69.6	71.1
Average size of priority areas (km^2)	2,157	2,114
% Network already protected	4.3	4.3
% Fishing footprint in the network	23.0	19.1
% Fishing effort in the network	28.2	25.0
Replication		
N priority areas	62	63
N priority areas larger than 100km^2	55	61
Connectivity		
Ave distance to closest neighbour (km)	39.2	38.0
Max distance to closest neighbour (km)	120.8	142.7
% Isolated priority areas (dist. >100km)	4.8	4.8
% Network area that is isolated	14.8	16.3
% Highly connected areas*	3.2	9.5
% Network area that is highly connected	1.1	10.9

* ≥10 neighbours and max. distance to closest neighbour ≤ 100km

The representative approach applied to the simplified network of priority areas, increased the representativity of most features that were underrepresented and helped achieving most feature's representation targets (Table 30). This is mostly evident for the deeper features, such as the proportion of the 1200-2500 m and >2500 m depth strata in the network and the seabed habitat "Flat areas" (i.e. abyssal plains). The proportion of the high and low relief seabed habitats was significantly increased to levels way above the target of 15% (Table 30).

No major differences in the performance assessment criteria used to evaluate commercially important fish and vulnerable deep-sea sharks/rays were noted when comparing the prioritization approach with the improved network of simplified priority areas (Table 31). One aspect that should be noted is the slight decrease in the proportion of the commercial fish habitat suitability index inside the fishing footprint; observed both in the area-based and fisheries-based cost models. On the contrary, the improved network of simplified priority areas contain a higher proportion of the cold-water coral habitat; also way above the target of 15% (Table 32).

Table 30. Performance assessment of the "representativity" design criteria for different conservation planning scenarios developed for deep Azores ecosystems. These scenarios considered a) one spatial planning area targets (15%), 2) one configurations of priority areas for management and conservation design (medium clumping), and c) two cost models (fishing cost, and area-based cost).

Spatial planning area targets	15%	
Cost	AB	FB
Clumping	Med.	
Representativity		
Depth strata in the network		
% 0-600 m depth in network	23.8	23.0
% 600-800 m depth in network	18.0	15.7
% 800-1200 m depth in network	16.6	15.7
% 1200-2500 m depth in network	13.5	12.9
% >2500 m depth in network	14.3	14.6
GMUs in the network		
% Island Shelf included	27.9	28.2
% Island Shelf Unit included	12.4	10.4
% High Relief included	48.4	51.2
% High Relief Unit included	40.1	40.3
% Low relief included	35.6	33.7
% Low relief Unit included	33.5	30.5
% Depression included	27.0	26.4
% Flat area included	9.5	9.7
% Hills included	22.0	21.5
N GMUs achieved target		
Seamounts in the network		
% Shallow smts in network (<800m)	32.2	29.6
% Inter. smts in network (800-1500)	22.7	24.2
% Deep smts the network (>1500m)	38.2	41.2

Table 31. Performance assessment of the first set of "important resources" design criteria for different conservation planning scenarios developed for deep Azores ecosystems. These scenarios considered a) one spatial planning area targets (15%), 2) one configurations of priority areas for management and conservation design (medium clumping), and c) two cost models (fishing cost, and area-based cost).

Spatial planning area targets	15%	
Cost	AB	FB
Clumping	Med.	
Important resources *("data-rich" area)*		
Commercially important fish		
% Fish HSI in network	21.0	19.9
% Fish habitat (HSI > threshold) in network	25.3	23.0
Avg. fish HSI (0-1) in network	0.19	0.20
% Fish predicted abundance in network	24.5	23.0
% Fish HSI in "protect" (out fishing footprint)	1.3	1.4
% Fish HSI in "restore" (in fishing footprint)	19.7	18.5
Vulnerable deep-sea sharks/rays		
% Sharks/rays HSI in network	16.5	15.1
% Sharks/rays habitat (HSI > threshold) in network	18.9	17.5
Avg. Sharks/rays HSI (0-1) in network	0.20	0.20
% Sharks/rays predicted abund. in network	16.8	15.0
% Sharks/rays HSI in "protect" (out fishing footprint)	6.5	6.5
% Sharks/rays HSI in "restore" (in fishing footprint)	10.0	8.6

Table 32. Performance assessment of the second set of "important resources" design criteria for different conservation planning scenarios developed for deep Azores ecosystems. These scenarios considered a) one spatial planning area targets (15%), 2) one configurations of priority areas for management and conservation design (medium clumping), and c) two cost models (fishing cost, and area-based cost).

Spatial planning area targets	15%	
Cost	AB	FB
Clumping	Med.	
Important resources *("data-rich" area)*		
Habitat-structuring CWC		
% CWC HSI in network	35.3	34.2
% CWC habitat (HSI > threshold) in network	28.0	26.6
Avg. CWC HSI (rescaled to 0-1) in network	0.26	0.26
% CWC HSI in "protect" (out fishing footprint)	5.6	6.1
% CWC HSI in "restore" (in fishing footprint)	29.8	28.1
Observed habitat-structuring CWC		
% CWC records in network	44.6	42.8
% CWC records in "protect" (out fishing footprint)	12.9	12.9
% CWC records in "restore" (in fishing footprint)	31.7	29.9
Inferred VMEs		
% VME index in network	32.0	30.4
Avg. VME index (rescaled to 0-1) in network	0.87	0.88
% VME index in "protect" (out fishing footprint)	7.9	8.8
% VME index in "restore" (in fishing footprint)	24.2	21.6

9.4.2 *Open-ocean*

The systematic conservation planning framework developed here aimed to inform the selection of "no-take areas" in the deep-sea of the Azores EEZ. It therefore, did not took into account the complexity of the open-ocean and pelagic environments. However, following the recommendations from the first scientific workshop and subsequent interactions with various stakeholders, we were asked to implement a simple assessment of the performance of the simplified and complemented network of priority areas for the pelagic environment. We acknowledge that the authors of this report have no expertise on this subject and, therefore, this performance assessment is merely as overlay of the network of priority areas design for the deep-sea with the publicly available spatial data for the open-ocean (Appendix 1).

The open-ocean and pelagic environments has been subject to diverse scientific studies and data collection frameworks in the Azores. Particularly, the Azores fisheries observer programme (POPA; http://www.okeanos.uac.pt/popa/index_EN.htm) has collected substantial amounts of spatial information that have supported various scientific studies on the ecology of cetaceans (e.g., Silva et al., 2014; Tobeña et al., 2016; Prieto et al., 2017), seabirds (e.g., Amorim et al., 2009), marine turtles (e.g., Vandeperre et al., 2019) and large pelagic sharks (e.g., Afonso et al., 2014; Fontes et al., 2020). However, these studies do not cover the whole EEZ of the Azores and focused mostly on the areas sampled by the observers' on-broad the pole-and-line fishing vessels. For example, the cetaceans' predictive distribution models covered only an area up to 150nm from the island shore (Tobeña et al., 2016; Prieto et al., 2017) while the seabirds' predictive distribution models covered only a box encompassing all the Azores islands (Amorim et al., 2009).

In the brief performance evaluation for the pelagic environment, we simply superimposed the simplified network of priority areas with the available spatial datasets on the distribution of marine pelagic fauna; i.e. cetaceans (Tobeña et al., 2016). Similarly to the other important resources (Section 5.7), we have assessed this criterion using the proportion of the predicted habitat suitability index inside the simplified and complemented network of priority areas. We have also assessed the overlap between the priority areas and estimates of fishing effort for pelagic gears produced with an analyses of the VMS data (Section 5.3.1). These layers contained the sum of the fishing effort measured as an estimate of the time spent fishing in each PU and were also converted in layers of present-day fishing footprint. The fishing effort layers for the pelagic environment were produced for the pelagic longline for the Azorean (2006-2018), mainland Portugal (2002-2018), and European fleets (2006-2015), and for the pole-and-line fishing fleet (2002-2010).

The simplified network of priority areas that resulted from complementing the prioritization network with a representativity and connectivity approach, overlaps with approx. 12% of the cetaceans' habitat suitability index (Table 33). The cetaceans evaluated by Tobeña et al. (2016) were the baleen whales (genus *Balaneoptera*), sperm and beaked whales (genera *Physeter*, *Mesoplodon*, *Hyperoodon*, and *Ziphius*), small dolphins (genera *Delphinus*, *Stenella*, and *Tursiops*), and large dolphins (genera *Globicephala*, *Grampus*, *Orcinus*, and *Pseudorca*). No major differences between the area-based and fisheries-based cost models were noted (Table 33). The spatial overlap between the simplified network of priority areas and the predicted habitat suitability varied among the different groups of species (Figure 91). In general, the priority areas overlapped with the predicted suitable habitat of sperm whales mostly in the SW region of the planning area, of baleen whales mostly in the NW region, and of beaked whales mostly in the southern region. The overlap with the predicted suitable habitat of large dolphins was most notorious around Princesa Alice bank in the some seamounts along the MAR (Figure 91), while with small dolphins (not in figure) was mostly in the Western region and south of Faial and Pico islands.

The simplified network of priority areas overlaps with both the present-day fishing effort of pelagic longline (15%) and pole-and-line (21%) gears (Table 33). In terms of pelagic longline fishing effort, the network of priority areas overlaps mostly with the EU fleet (19%) and the mainland Portugal fleet (12%-13%). The network overlaps with 10 to 12% of the Azores pelagic longline effort and with 21% to 22% of the pole-and-line effort in the area-based and fishing-based cost models, respectively (Table 33). In general, the spatial overlap with the local Azores pelagic longline fleet was most evident in the Princesa Alice bank and in the Voador seamount, while for the pole-and-line fishing the overlap was greater eastern group of the Archipelago around São Miguel and Santa Maria islands but also around the Princesa Alice bank and south of Pico island (Figure 92). The overlap with the mainland Portugal longline fleet was most evident in the seamount around the south portion of the MAR and in the NE of the EEZ, while for the EU fleet the overlap was most evident in the SW portion of the EEZ (Figure 92).

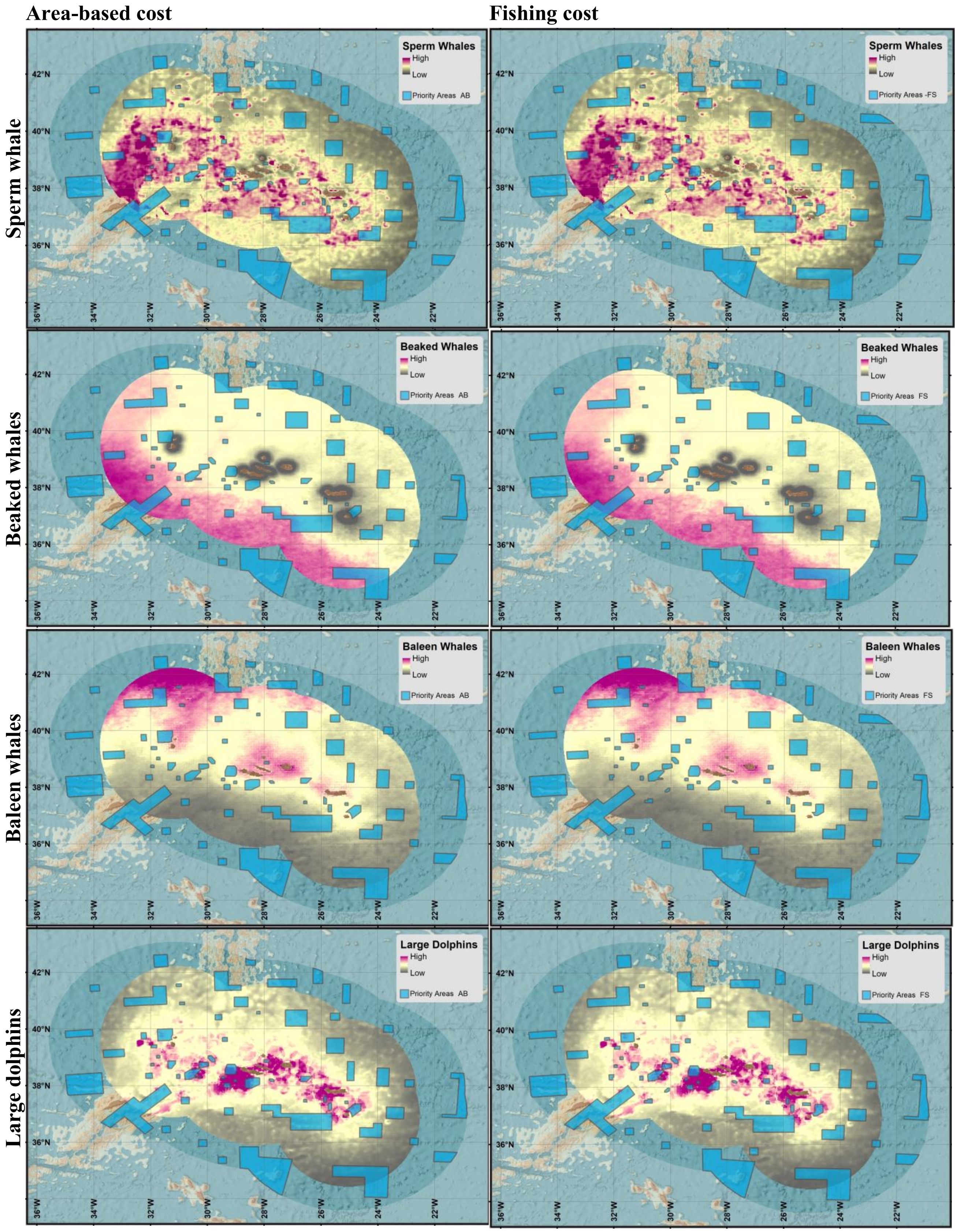


Figure 91. Overlaying the network of simplified priority areas with the available spatial datasets on the distribution of cetaceans in the Azores for the area-based cost scenarios (left) and the fisheries-based cost scenarios (right).

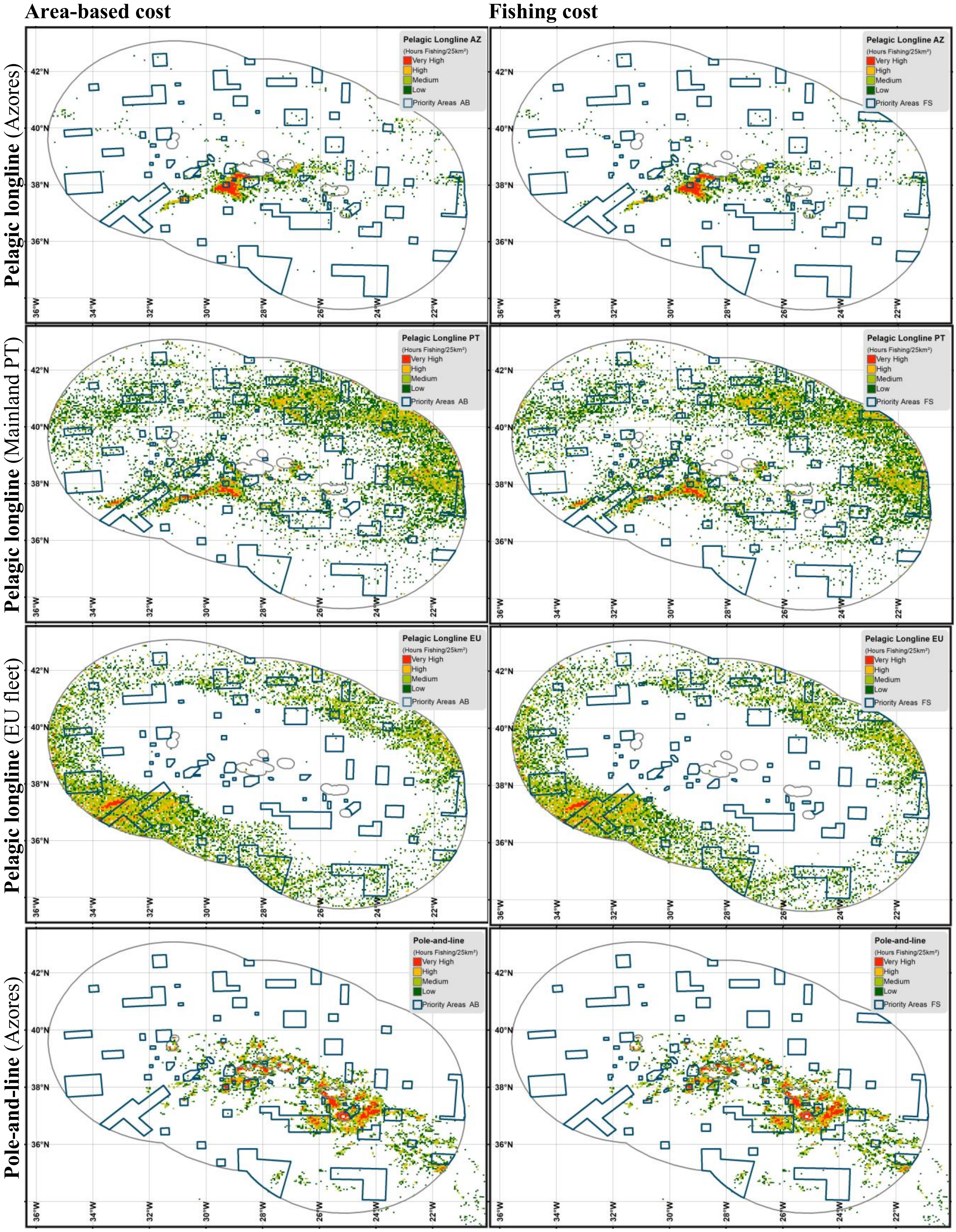


Figure 92. Overlaying the network of simplified priority areas with estimates of fishing effort for pelagic gears produced with an analyses of the VMS data in the Azores for the area-based cost scenarios (left) and the fisheries-based cost scenarios (right).

Table 33. Brief performance evaluation for the pelagic environment considering different conservation planning scenarios. These scenarios considered a) one spatial planning area targets (15%), 2) one configurations of priority areas for management and conservation design (medium clumping), and c) two cost models (fishing cost, and area-based cost).

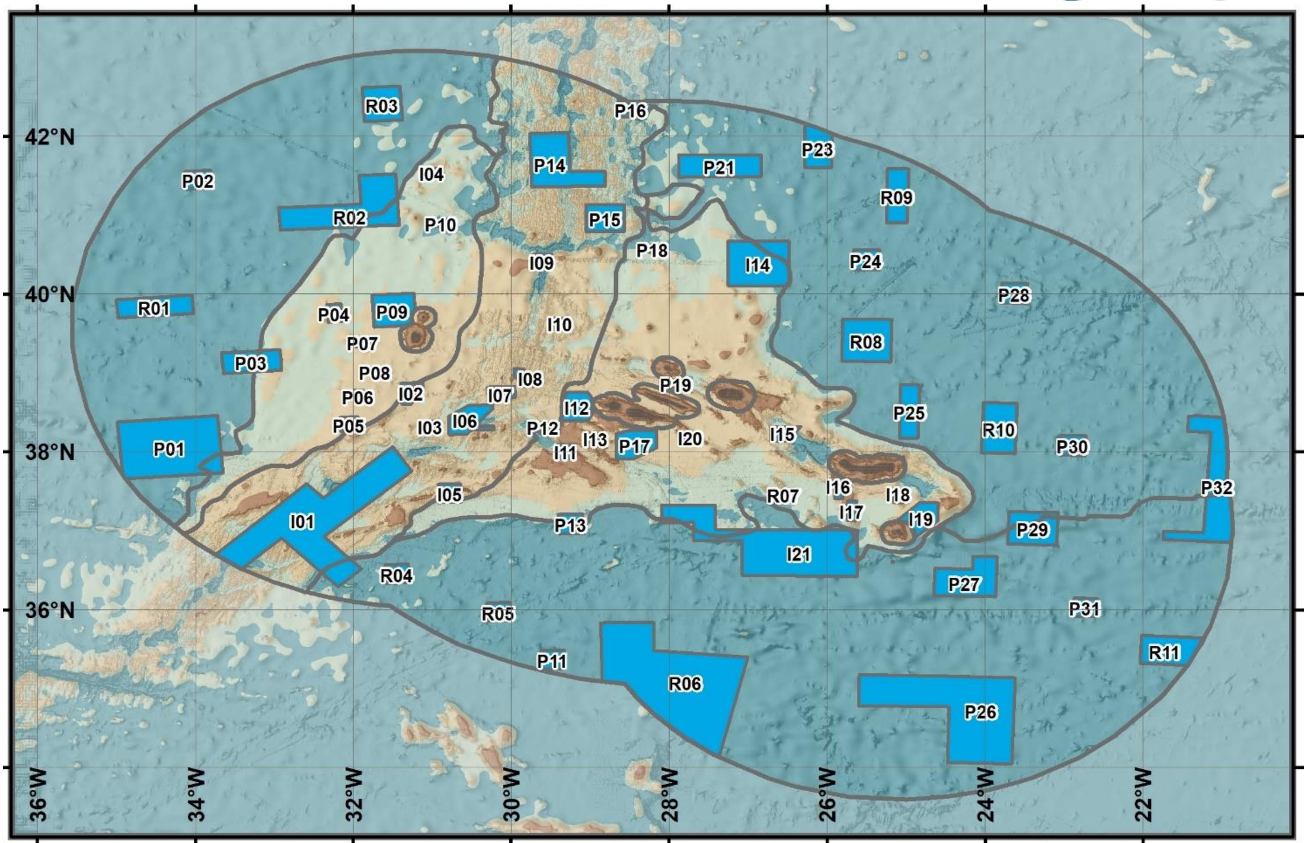
Spatial planning area targets	15%	
Cost	AB	FB
Clumping	Med.	
Viability and adequacy		
% Pelagic longline fishing		
% footprint in the whole network	14.1	13.9
% effort in the whole network	15.4	15.1
% footprint in the network (Azores fleet)	10.9	11.0
% effort in the network (Azores fleet)	10.4	12.3
% footprint in the network (Mainland PT fleet)	13.2	13.0
% effort in the network (Mainland PT fleet)	13.3	12.4
% footprint in the network (EU fleet)	17.1	16.8
% effort in the network (EU fleet)	19.4	19.1
% Pole-and-line fishing footprint in the network	15.5	14.8
% Pole-and-line fishing effort in the network	22.1	20.7
Important resources *("data-rich" and "data-poor" areas)*		
Cetaceans		
% Small dolphins HSI in network	12.3	11.9
% Large dolphins HSI in network	12.8	12.2
% Baleen whales HSI in network	11.8	11.5
% Sperm whales HSI in network	12.3	12.0
% Beaked whales HSI in network	12.8	12.6
Avg. Cetaceans HSI (rescaled to 0-1) in network	12.3	11.9

10. Final simplified prioritization solutions

We developed summary factsheets for the resulting list of priority areas that synthetize the best-available information that originated their designation and may stimulate the discussions. These factsheets aim to stimulate the discussion around the basis that originated their designation. It should be stressed again that the objective of this list is not to indicate the preferred design and placement of fisheries closures in the Azores, but rather to summarize the outputs of the systematic conservation planning approach and to inform the discussions around this topic. The areas described in the factsheets are summarized in Table 34, and in Figure 93 for the area-based cost model and in Figure 94 for the varying fisheries-based cost.

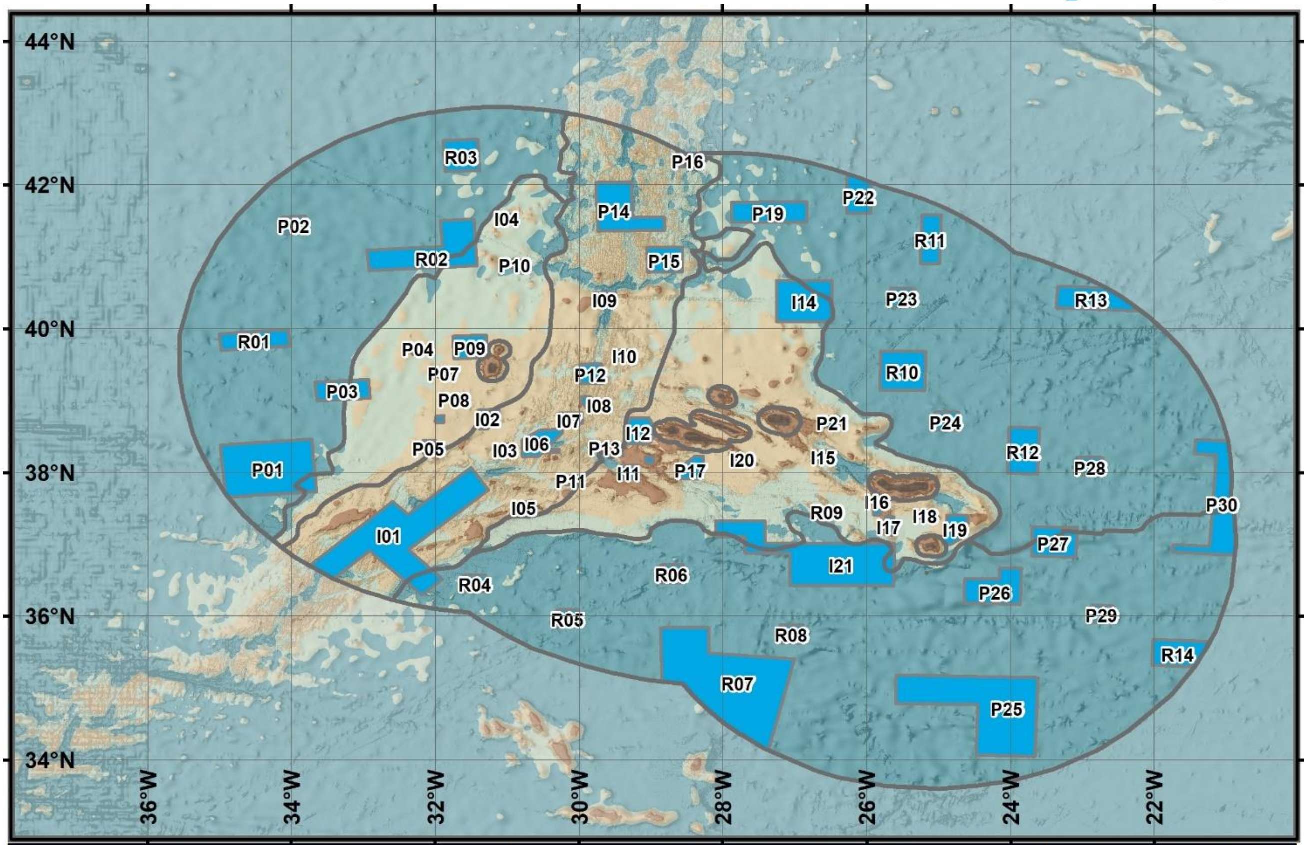
Table 34. List of the resulting simplified networks of priority areas. 57 areas appeared in both the area-based and the varying fisheries-based cost models, 5 that appeared only in the area-based and 6 only in the fisheries-based cost.

Priority Areas (Important Areas)	**Area-based**	**Fish.-based**	**Priority Areas (Prioritization approach)**	**Area-based**	**Fish.-based**	**Priority Areas (Represent. & Connect.)**	**Area-based**	**Fish.-based**
MAR Azores SW	•	•	Pico Fracture Zone	•	•	Azores West	•	•
Diogo de Teive	•	•	Flores Oceânico	•	•	Corvo Oceânico	•	•
Beta	•	•	Sarda North	•	•	North of Hard Rock Café	•	•
Hard Rock Café	•	•	West of Corvo	•	•	Monte Alto South	•	•
Voador	•	•	Buchanan	•	•	North of Atlantis	•	•
Cavala	•	•	Bugio South	•	•	Abyssal Princesa Alice		•
Gigante SW & 127	•	•	Cachalote	•	•	Pico Sul/Meteor North	•	•
Gigante/Luso	•	•	Búgio North	•	•	Abyssal Pico Sul		•
Kurchatov	•	•	Flores and Corvo	•	•	Girard Ridge South	•	•
Oscar	•	•	Kurchatov West	•	•	East of Borda	•	•
Princesa Alice	•	•	East of Pico Sul	•		S. Miguel Oceânico	•	•
Condor	•	•	Alberto do Monaco North		•	Abyssal São Miguel	•	•
Açor	•	•	Gigante North		•	Azores NE		•
Sedlo	•	•	Condor de Fora West	•	•	Azores SE	•	•
Dom João de Castro	•	•	Pettersson Escarpment	•				
Mar da Prata Norte	•	•	Faial Oceânico	•	•			
Mar da Prata South	•	•	Kurchatov NE	•	•			
Grande Norte	•	•	Chaucer East	•	•			
Formigas/Dollabarat Bank	•	•	São Mateus South	•	•			
Pico SE	•	•	East of Kurchatov	•				
Deep seamounts/ Pico Depression	•	•	Ilha Azul	•				
			Graciosa Oceânico	•	•			
			Maçarico East		•			
			Terceira Oceânico	•	•			
			Sedlo East	•	•			
			East of Heitor Alves	•	•			
			Santa Maria Oceânico	•	•			
			South of Gonçalo Velho	•	•			
			Low relieves NE	•				
			Gloria Fracture Z.	•	•			
			São Miguel East	•	•			
			Azores East Fracture Z.	•	•			
			Azores East	•	•			



Important Areas		Prioritization Approach		Representativity
I01 MAR Azores SW	I16 Mar da Prata North	P01 Pico Fracture Z.	P16 Chaucer East	R01 Azores West
I02 Diogo de Teive	I17 Mar da Prata South	P02 Flores Oceânico	P17 S. Mateus South	R02 Corvo Oceânico
I03 Beta	I18 Grande Norte	P03 Sarda North	P18 East of Kurchatov	R03 North of HRC
I04 Hard Rock Café	I19 Formigas/Dollabarat Bank	P04 West of Corvo	P19 Ilha Azul	R04 Monte Alto South
I05 Voador	I20 Pico SE	P05 Buchanan	P21 Graciosa Oceânico	R05 North of Atlantis
I06 Cavala	I21 Deep Smt./Pico Depression	P06 Bugio South	P23 Terceira Oceânico	R06 Pico Sul/Meteor North
I07 Gigante 127		P07 Cachalote	P24 Sedlo East	R07 Girard Ridge South
I08 Gigante/Luso		P08 Bugio North	P25 East of Heitor Alves	R08 East of Borda
I09 Kurchatov		P09 Flores and Corvo	P26 Santa Maria Oceânico	R09 S. Miguel Oceânico
I10 Oscar		P10 Kurchatov West	P27 South of Gonçalo Velho	R10 Abyssal São Miguel
I11 Princesa Alice		P11 East of Pico Sul	P28 NE EEZ	R11 Azores SE
I12 Condor		P12 Condor de Fora West	P29 Gloria Fracture Z.	
I13 Açor		P13 Pettersson Escarpment	P30 São Miguel East	
I14 Sedlo		P14 Faial Oceânico	P31 Azores East Frature Z.	
I15 Dom João de Castro		P15 Kurchatov NE	P32 Azores East	

Figure 93. List of priority areas for management and conservation resulting from the systematic conservation planning scenarios considering the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores, and using the area-based cost model.

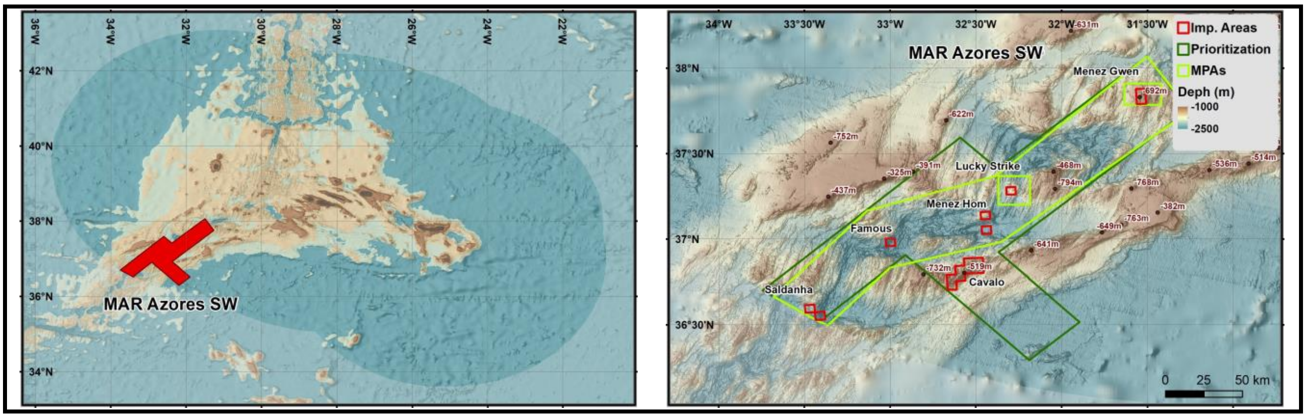


Important Areas		Prioritization Approach		Representativity
I01 MAR Azores SW	I15 Dom João de Castro	P01 Pico Fracture Z.	P15 Kurchatov NE	R01 Azores West
I02 Diogo de Teive	I16 Mar da Prata North	P02 Flores Oceânico	P16 Chaucer East	R02 Corvo Oceânico
I03 Beta	I17 Mar da Prata South	P03 Sarda North	P17 S. Mateus South	R03 North of HRC
I04 Hard Rock Café	I18 Grande Norte	P04 West of Corvo	P19 Graciosa Oceânico	R04 Monte Alto South
I05 Voador	I19 Formigas/Dollabarat Bank	P05 Buchanan	P21 Maçarico East	R05 North of Atlantis
I06 Cavala	I20 Deep Smt./Pico Depression	P06 Bugio South	P22 Terceira Oceânico	R06 Abyssal Princesa Alice
I07 Gigante 127	I21 Pico Depression	P07 Cachalote	P23 Sedlo East	R07 Pico Sul/Meteor North
I08 Gigante/Luso		P08 Bugio North	P24 East of Heitor Alves	R08 Abyssal Pico Sul
I09 Kurchatov		P09 Flores and Corvo	P25 Santa Maria Oceânico	R09 Girard Ridge South
I10 Oscar		P10 Kurchatov West	P26 South of Gonçalo Velho	R10 East of Borda
I11 Princesa Alice		P11 Alberto do Monaco North	P27 Gloria Fracture Z.	R11 S. Miguel Oceânico
I12 Condor		P12 Gigante North	P28 São Miguel East	R12 Abyssal São Miguel
I13 Açor		P13 Condor de Fora West	P29 Azores East Frature Z.	R13 Azores NE
I14 Sedlo		P14 Faial Oceânico	P30 Azores East	R14 Azores SE

Figure 94. List of priority areas for management and conservation resulting from the systematic conservation planning scenarios considering the overarching goal of restoring fish stocks of deep-sea species while protecting natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in the Azores, and using the varying fisheries-based cost model.

MAR Azores SW

Cost model	AB + FS		**Area** (km)	13,644
Type	Ridge & seamounts		**Depth range** (m)	451-3707
Code	I01		**Distance neighbour** (km)	27
Classification criteria	Important area and MPA		**Bottom fishing effort** (%)	1.0
Main features	Hydrothermal vents and VME (Cavalo ridge)		**Existing MPAs**	PMA 02, 03, 13



Environmental setting

This area is located in the south portion of Mid Atlantic Ridge, near the 200 nm of the Azores EEZ. It is located about 130 nm SW of Faial. It covers mostly the valley of the MAR and encompasses all known active hydrothermal vents in the Azores (except Luso), namely Menez Gwen, Lucky Strike, the Menez Hom, Famous, Saldanha, and Amar vent fields. This area also includes a small ridge named Cavalo, on an area sometimes named the East Jussie Plateau, which was evaluated as a VME. This region is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

The prioritization area encompasses a series of hydrothermal vent fields, such as Lucky Strike and Menez Gwen, which host very specific benthic communities adapted to extreme environments. Regarding the seamount, hard substrates of the slopes are generally colonized by the primnoids *Narella versluysi* and *Narella bellissima*, forming in Cavalo large areas of high densities. This diverse community is associated to a wide range of species, including sponges (e.g. *Haliclona magna*, cf. cf. *Poecillastra compressa*) and large corals (*Paragorgia johnsoni*, *Pleuricorallium johnsoni*, *Callogorgia verticillata)*. Areas close to the summit host some very large colonies of *Paragorgia johnsoni* with laminate sponges of the species cf. *Pachastrella monilifera*, not common in such densities elsewhere. When the rock acquires a darker tonality, a sponge-dominated community is observed. The summit is characterized by the yellow gorgonian of the genus *Acanthogorgia* and very large colonies of the octocoral *Callogorgia verticillata*.

Images of benthic communities

Image credits: © Hopper cam, NIOZ / Cruise 64PE441

If a VME

This area encompasses a series of hydrothermal vent fields. Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of species and communities. Dense coral gardens dominated by octocorals *Narella versluysi* and *N. bellissima*, largest aggregation recorded in the Azores so far. Presence of large colonies of the octocorals *Paragorgia johnsoni* and *Callogorgia verticillata*, which are slow-growing, long-lived species susceptible to fishing.

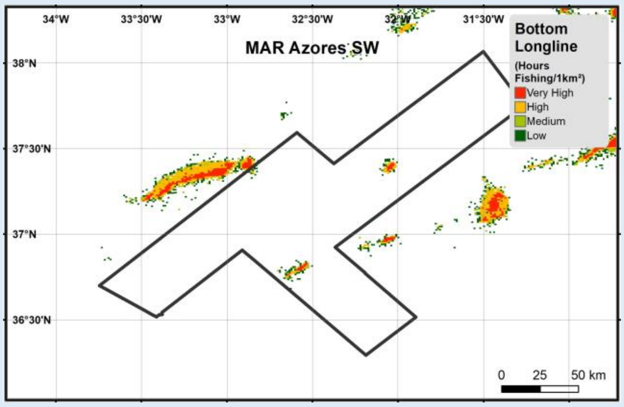
Existing regulations

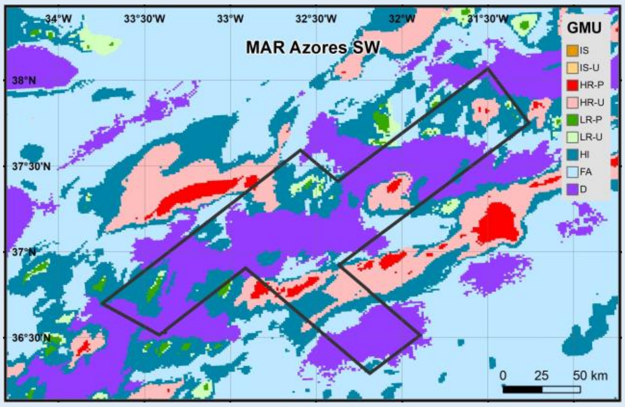
A large portion of the MAR Azores SW area is contained in the Azores Marine Park (PMA 13) but lack effective protection measures (DLR 13/2016/A). In fact, deep-sea mining exploration activities are not prohibited in PMA13. The hydrothermal vents Menez Gwen (PMA 02) and Lucky Strike (PMA 03) are Nature Reserves and protected against bottom contact fishing, deep-sea mining, dumping and other activities that may cause harm to the marine environment (IUCN category I; DLR 28/2011/A). This area lies within the area for protection of deep-water corals from the effects of fishing; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation No. 1568/2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This area mostly lies beyond 100 nautical miles from the island shores and therefore are accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

Human activities

The MAR Azores SW area has reduced importance for the local bottom and pelagic longline fleets or the pole-and-line fleet. However, this area is highly used by the EU pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and is occasionally visited by mainland Portugal pelagic longliners. This area raised interest for deep-sea mining exploration.

Fishing intensity — Seabed Habitats





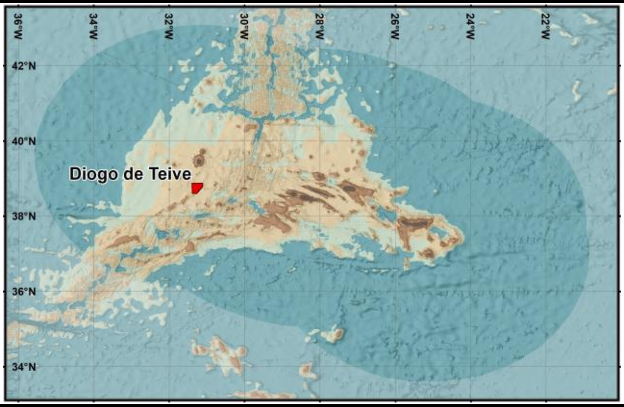
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	Several dives from different cruises specifically in and around the hydrothermal vent fields; 1 dive with the Hopper tow-cam in Cavalo between 590 and 630 m

Diogo de Teive

Cost model	AB + FS
Type	Seamount
Code	I02
Classification criteria	Important area
Main features	Near-natural area

Area (km)	572
Depth range (m)	583-2122
Distance neighbour (km)	26
Bottom fishing effort (%)	-
Existing MPAs	-



Environmental setting

The Diogo de Teive seamount is on the western side of Mid Atlantic Ridge between the Açor Bank and Faial-Pico Fracture zones. It is located in the North American tectonic plate, about 30 nm south of the closest island (Flores). The Diogo de Teive was considered a near-natural important area and might be under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

There is currently no information available regarding the composition and structure of the benthic communities present in this seamount.

Images of benthic communities

There are currently no images available regarding the benthic habitats of this seamount.

If a VME

The lack of fishing pressure derived from the analyses of VMS data indicated that Diogo de Teive might be one of the few near-pristine seamounts remaining in the Azores region. Areas with near-natural structures, processes and functions are important reference sites that can help setting conservation goals and objectives, guiding trajectories of recovery of impacted sites, and inform adaptive management, and for this reason Diogo de Teive was considered of high conservation importance.

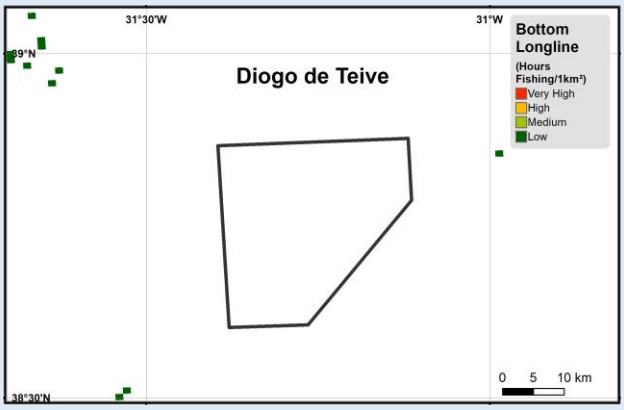
Existing regulations

The Diogo de Teive seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

After a careful look at the VMS data, no indication of bottom fisheries could be identified in Diogo de Teive, which raised the hypothesis that this seamount might be a near-natural deep-sea area. Diogo de Teive is only occasionally visited by the pelagic longlining fleets from mainland Portugal targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*). The analyses of the VMS data showed no indication of visits to this seamount by the local pole-and-line fleet targeting tuna species or the local pelagic longlining fleet.

Fishing intensity | Seabed Habitats



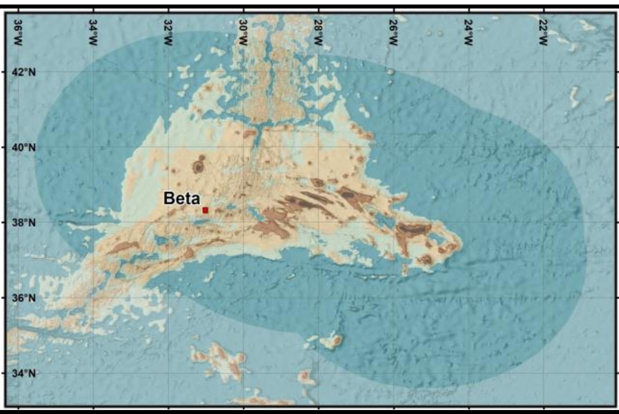
Scientific knowledge

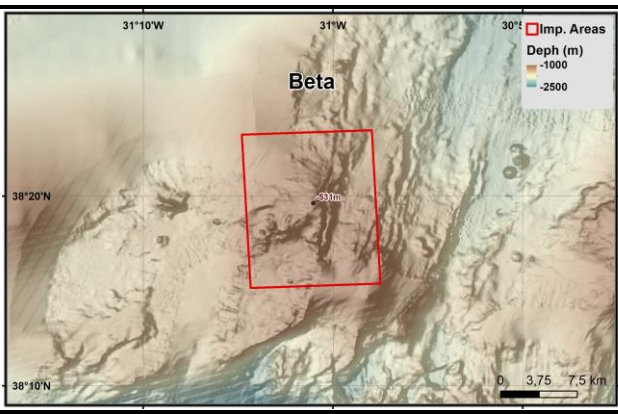
Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Beta seamount

Cost model	AB + FB
Type	Seamounts
Code	I03
Classification criteria	Important area
Main features	Known VME

Area (km)	150
Depth range (m)	531-1439
Distance neighbour (km)	15
Bottom fishing effort (%)	0.2
Existing MPAs	-





Environmental setting

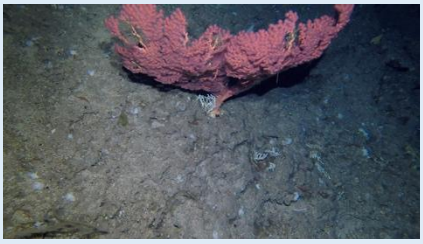
Beta is a seamount produced by fissural volcanism along the central ridge and transform faults, lying in the main axis of the Mid Atlantic Ridge between the Açor Bank and Faial-Pico Fracture zones. It is located about 60 nm south of the closest island (Flores) and about 100 nm west of Faial Island. Beta seamount is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

The deepest areas explored are characterized by coral rubble of an unknown origin. When the substrate becomes more consolidated, the density of the primnoids *Narella versluysi* and *Narella bellissima* increases, as well as that of the anthozoan *Pseudoanthomastus* cf. *agaricus* and the glass sponge *Asconema* sp. In shallower depths, the community changes to a more complex and diverse association, in which a large number of species can be identified: the white gorgonian *Pleurocorallium johnsoni*, large porifera cf. *Characella pachastrelloides*, the yellow laminate sponge cf. *Poecillastra compressa*, a wide variety of encrusting sponges and a very abundant small Plexauridae of the genus *Swiftia*. Also on the slopes but further up towards the summit, the bubblegum coral *Paragorgia johnsoni* in its red and white morphs starts to appear, with colonies reaching some of the largest sizes recorded in the Azores region. On the flat areas of the summit, a remarkable aggregation of the Rossellidae sponge *Asconema* sp. was registered.

Images of benthic communities

Image credits: © IMAR/OKEANOS-UAz, Drift camera


If a VME

Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Dense and diverse coral gardens dominated by large octocorals and sponge aggregations. Dense *Paragorgia johnsoni* gardens with some very large colonies. Communities generally well preserved, showing little impact from fishing.

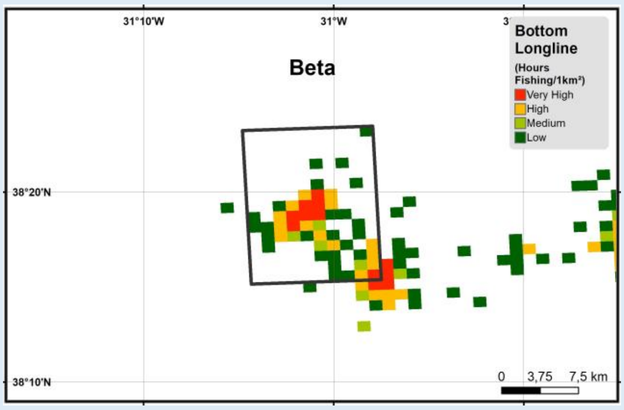
Existing regulations

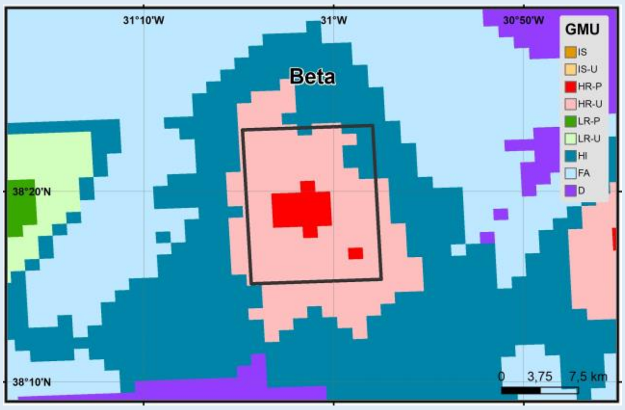
The Beta seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

Beta seamount is an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This seamount is also highly used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and occasionally visited by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also visited this seamount.

Fishing intensity | Seabed Habitats



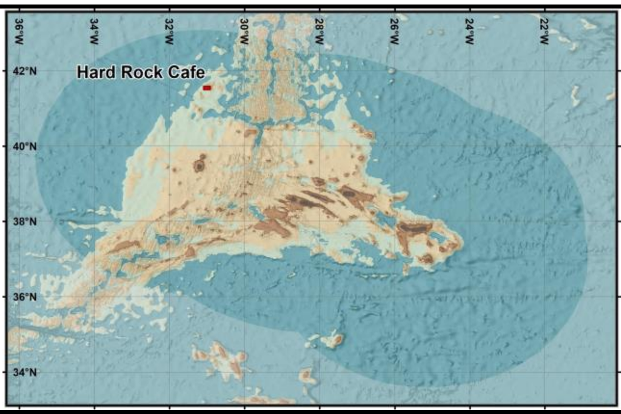


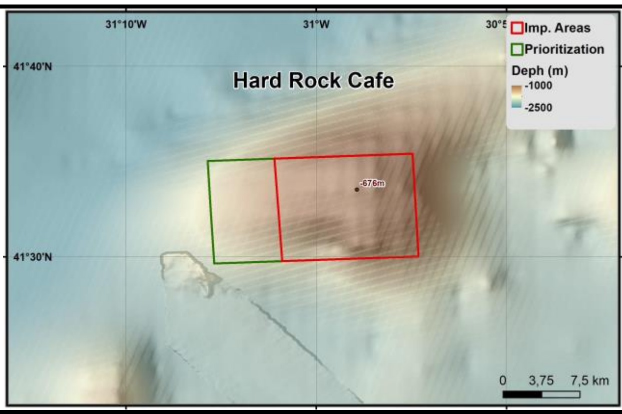
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	5 dives with the drift-cam system between 540-695 m depth.

Hard Rock Café

Cost model	AB + FS	**Area** (km)	150
Type	Seamount	**Depth range** (m)	630-1892
Code	I04	**Distance neighbour** (km)	31
Classification criteria	Importat Area	**Bottom fishing effort** (%)	-
Main features	Essential fish habitat	**Existing MPAs**	-





Environmental setting

The Hard-Rock Café is a remote seamount located in the NW region of the Azores EEZ, in the North American tectonic plate. It located North of the Kurchatov Fracture Zone, about 100 nm north of the closest island (Corvo). This seamount is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

Although there is currently no information regarding the composition and structure of the benthic communities that exist on Hard Rock Café, fishing experiments have provided evidence of how important this seamount is for several deep-sea fish populations. For example, the endangered orange roughy (*Hoplostetus atlanticus*) uses this seamount as a reproductive ground, and experimental captures have shown the importance with regards of its stocks in the Azores, possibly hosting the second largest population in the region.

Images of benthic communities

There are currently no images available regarding the benthic habitats of this seamount.

If a VME

The Hard Rock Cafe seamount was considered an Essential Fish Habitat because of the large spawning aggregations for orange roughy observed during trawl bottom fishing experiments. Although we recognize that there is an insufficient understanding of what is an essential habitat in the Azores, this area was considered of conservation importance.

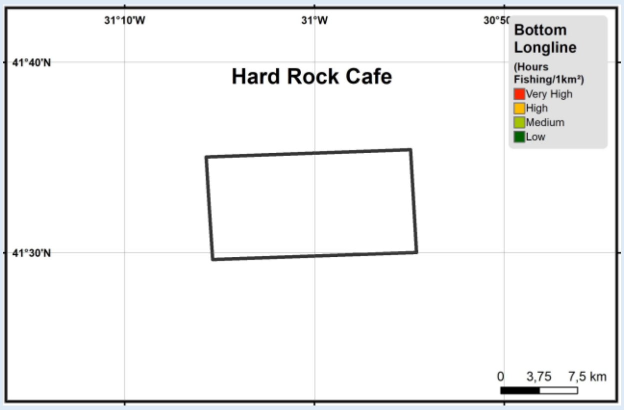
Existing regulations

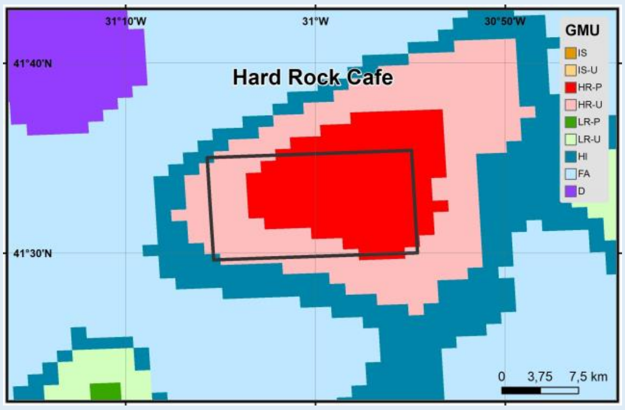
The Hard-Rock Café seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. However, this seamount lies beyond 100 nautical miles from the baselines of the Union outermost regions and therefore are accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

Human activities

The Hard-Rock Café is a remote seamount with reduced importance to the local bottom longline, pelagic longlining or pole-and-line fishing fleets. However, this seamount was surveyed during a bottom trawl fishing experiment and large aggregations of orange roughy (*Hoplostethus atlanticus*) were caught. This area is only rarely visited by the mainland Portugal and other EU countries pelagic longlining fleets targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*).

Fishing intensity | Seabed Habitats





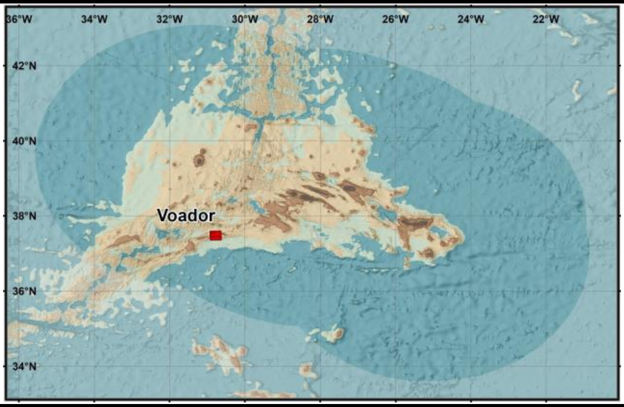
Scientific knowledge

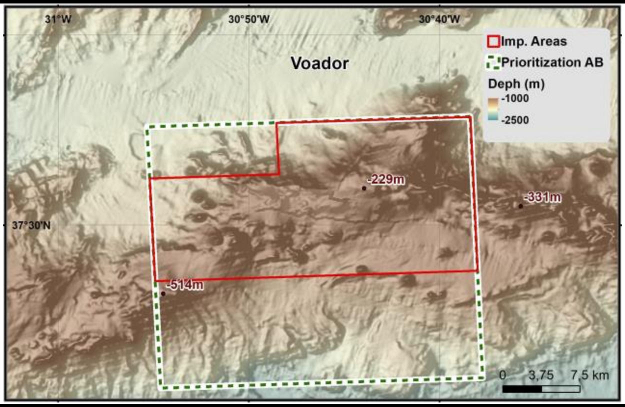
Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Voador

Cost model	AB≠FS
Type	Seamount
Code	I05
Classification criteria	Important area
Main features	Known VME, shallow seamount

	AB	FS
Area (km)	636	325
Depth range (m)	229-2157	229-1699
Dist. neighbour (km)	27	27
Bottom fishing effort (%)	1.0	1.0
Existing MPAs	-	-





Environmental setting

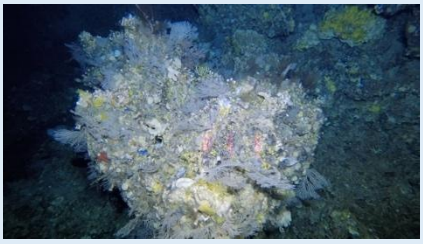
Voador seamount is located in the SE portion of Mid Atlantic Ridge near the West Azores Fracture Zone (a.k.a. Pico fracture zone). It is located in the portion of the MAR named Faial ridge (a.k.a. Alberto de Monaco Ridge) about 105 nm SW of the closest island (Faial). The Voador seamount is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

A sponge-dominated assemblage is commonly observed on the hard substrates of the slope, with several encrusting sponges and large erect species. The size of some cf. *Characella pachastrelloides* is remarkable, serving as substrate to other life forms. Some large *Callogorgia verticillata* colonies can also be observed on the smooth slopes generating monospecific patches, generally with little fauna associated. The association between the large primnoid *Paracalyptrophora josephinae* and a hydroid species is also observed, with the density of *P. josephinae* possibly the highest ever recorded in the Azores. Some large six-gill sharks (*Hexanchus griseus*) have also been reported from the slopes of this seamount too. Dense aggregations of *Candidella imbricata* appear in shallower areas, mainly developing over rocky outcrops and large boulders, with a high number of associated species.

Images of benthic communities

Image credits: © IMAR/OKEANOS-UAz, Drift camera



If a VME

Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of species and communities. Densest coral gardens of the octocoral *Paracalypthrophora josephinae* observed in the Azores so far, with the presence of tall colonies. Species highly susceptible to fishing based on bycatch data; and low growth rates and reproductive output. Dense aggregation of *Candidella imbricata* at shallow depths. Also a shallow-water seamount, potentially hotspot of biodiversity for benthic and pelagic fauna.

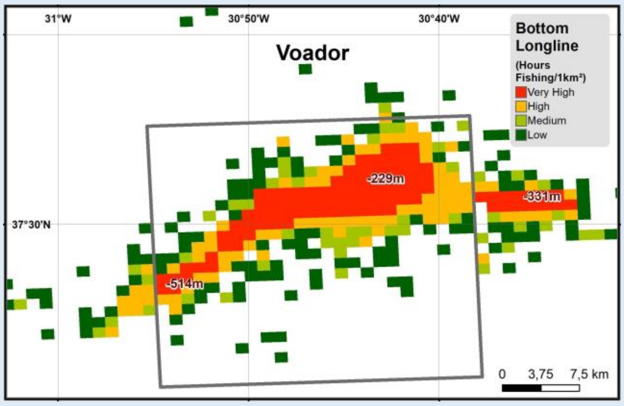
Existing regulations

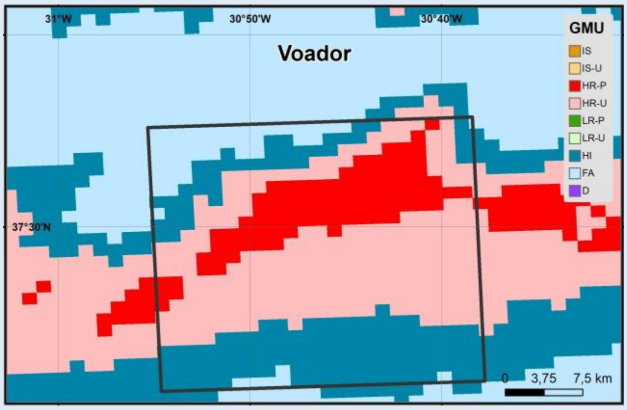
The Voador seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. However, this seamount lies beyond 100 nautical miles from the baselines of the Union outermost regions and therefore are accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

Human activities

Voador seamount is an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This seamount is also highly used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and occasionally visited by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal and other EU countries also visited this seamount.

Fishing intensity / Seabed Habitats





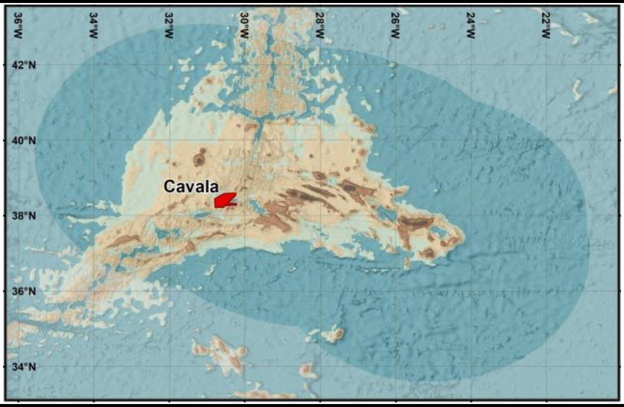
Scientific knowledge

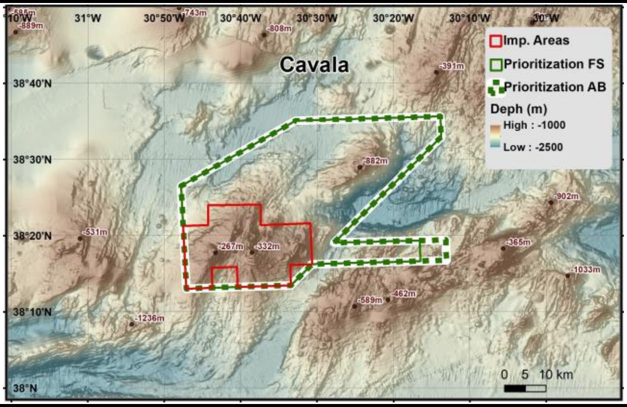
Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	16 dives with the drift-cam system between 260-590 m depth.

Cavala

Cost model	AB ≠ FS
Type	Seamount & Ridge
Code	I06
Classification criteria	Important area
Main features	Known VMEs

	AB	FS
Area (km)	1,426	1,401
Depth range (m)	267-2950	267-2950
Dist. neighbour (km)	5	5
Bottom fishing effort (%)	3.2	3.2
Existing MPAs	-	-





Environmental setting

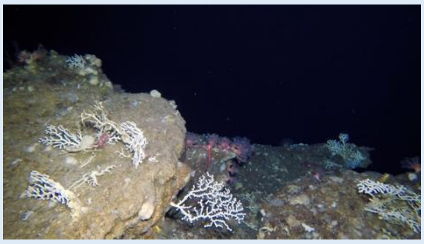
Cavala is a seamount produced by fissural volcanism along the central ridge and transform faults, lying in the main axis of the Mid Atlantic Ridge between the Açor Bank and Faial-Pico Fracture zones. This area also encompasses another semount-like feature named Bicuda. It is located about 60 nm south of the closest island (Flores) and about 80 nm west of Faial Island. Cavala seamount is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

The deepest areas explored have gravels and small volcanic rocks with glass sponges of the species *Pheronema carpenteri* and *Farrea occa*. At 500 m, large boulders and rocks are colonized by the white coral *Pleurocorallium johnsoni* and the laminate sponge cf. *Poecillastra compressa*. The density and size of *Paragorgia johnsoni* corals increases towards shallower depths, maintaining the composition of the associated fauna. Vertical or very steep walls have a dominance of encrusting and erect sponges (e.g. *Macandrewia azorica* and cf. *Petrosia crassa*). The benthic community changes when reaching the shallowest sectors, with a dominance of the whip coral *Viminella flagellum* in association with the sponges cf. *Characella pachastrelloides* and cf. *Petrosia crassa*, as well as other octocorals (*Acanthogorgia* cf. *hirsuta*, *Dentomuricea* aff. *meteor*, *Callogorgia verticillata* and *Paracalyptrophora josephinae*). An exceptionally dense aggregation of the sea fan *Dentomuricea* aff. *meteor* was identified in the summit, below 400 m depth.

Images of benthic communities

Image credits: © IMAR/OKEANOS-UAz, Drift camera

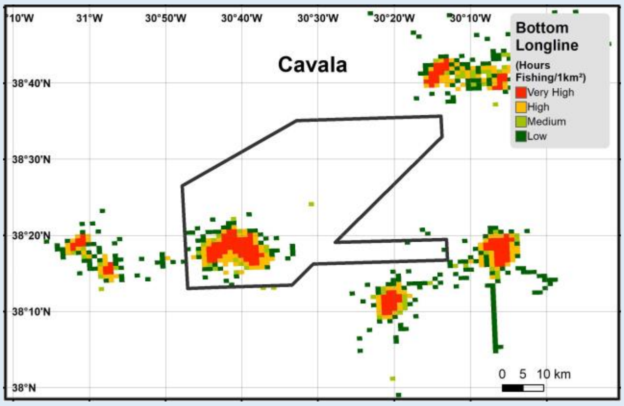


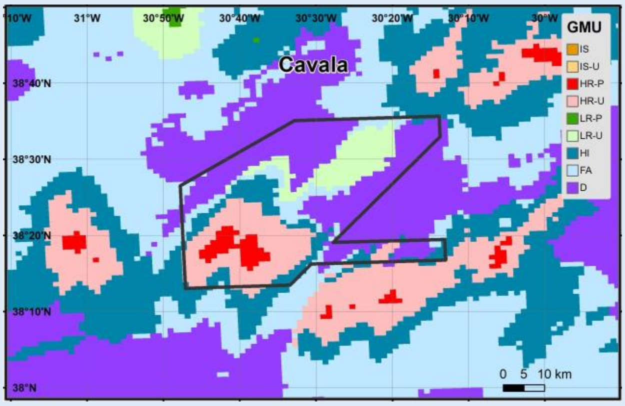
If a VME
Presence of likely endemic species *Dentomuricea* aff. *meteor*. High diversity of species and communities. Dense coral gardens dominated by *Dentomuricea* aff. *meteor,* one of the densest recorded in the Azores so far. Presence of large *Paragorgia johnsoni, Pleurocorallium johnsoni* and *Paracalypthrophora josephinae*, species highly susceptible to fishing based on bycatch data or evidence of broken colonies in video surveys. Structural species characterized by slow growth and low reproductive output.

Existing regulations
The Cavala seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities
The Cavala seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the island shores and therefore fishing is restricted to vessels registered in the Portuguese ports (EC 1380/2013; in place until December 2022).

Fishing intensity | **Seabed Habitats**



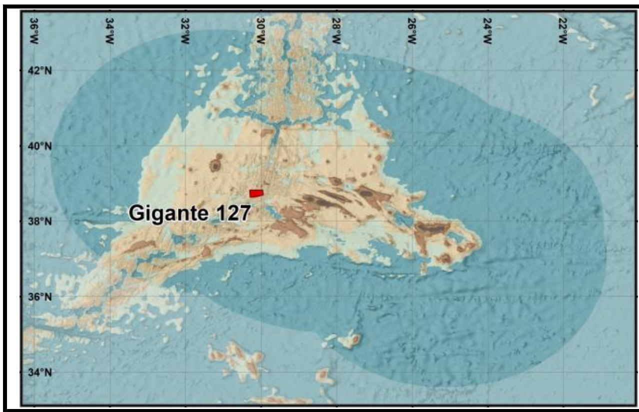


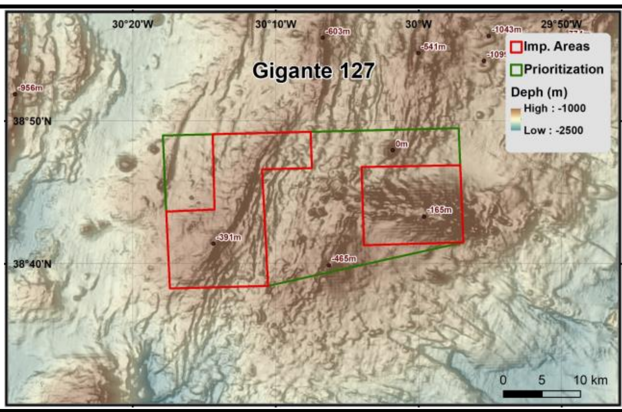
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	15 dives with the drift-cam system between 335-675 m depth.

Gigante SW & 127

Cost model	AB + FB	**Area** (km)	546
Type	Seamount & Ridge	**Depth range** (m)	166-1602
Code	I07	**Distance neighbour** (km)	5
Classification criteria	Important Area	**Bottom fishing effort** (%)	4.5
Main features	Known VME, shallow seamount	**Existing MPAs**	-





Environmental setting

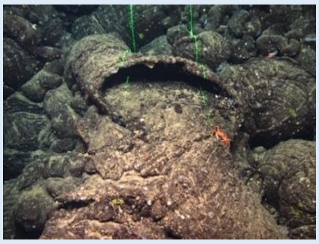
The Gigante seamount complex is located on the Mid-Atlantic Ridge, at around 39ºN / 30ºW, close to the triple junction of the North American, Nubian and Eurasian tectonic plates. The Gigante SW is a ridge-like structure associated with the MAR, with a NE/SW orientation, approximately 20 km long and 2.5 km wide. 127 seamount is likely a volcano produced by fissural volcanism associated with the central ridge with a W/E orientation and approximately 12 km long and 5 km wide. This area is situated about 55 nm west of Faial Island. This area is under the influence of a complex current system, which is still poorly known.

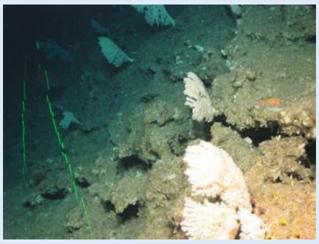
Biological benthic communities

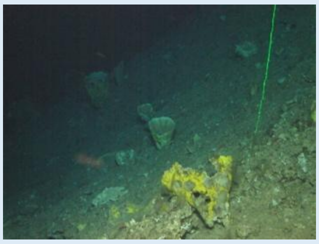
Some of the deepest zones explored in 127 seamount present large basaltic lava balloons, colonized by the flabellate sponge cf. *Poecillastra compressa* and the small white coral *Pleurocorallium johnsoni*. At those depths, sedimentary areas are home to solitary corals of the genus *Flabellum*. In the SW ridge, at 600 m depth, two main cold-water coral assemblages can be identified: one dominated by Scleraxonia species, with dominance of large *Paragorgia johnsoni* colonies, and the other by Holaxonia species, including *Anthothela*, *Swiftia* spp., *Acanthogorgia* sp. and *Pseudoanthomastus* spp. As depth decreases, new Coralliidae species appear and larger sponges become more frequent (*Leiodermatium lynceus*, cf. *Characella pachastrelloides*, cf. *Neophrissospongia nolitangere*, cf. *Poecillastra compressa*). Loose aggregations of *Viminella flagellum* are encountered at about 450 m, which become gradually denser and in association with *Acanthogorgia* and *Eguchipsammia* species. Below 450 m depth, *Nicella granifera*, *Elatopathes abietina* and *Dentomuricea* cf. *meteor* are also observed.

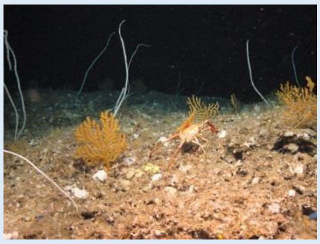
Images of benthic communities

Image credits: © ROV Luso/EMEPC / 2018 Oceano Azul Expedition









If a VME

Species with mixed amphi-Atlantic and Atlanto-Mediterranean distribution. Populations of CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*. Dense *Paragorgia johnsoni* gardens with some of the largest colonies recorded so far showing little impact from fishing. Shallow-water seamount, potentially a biodiversity hotspot of benthic and pelagic fauna.

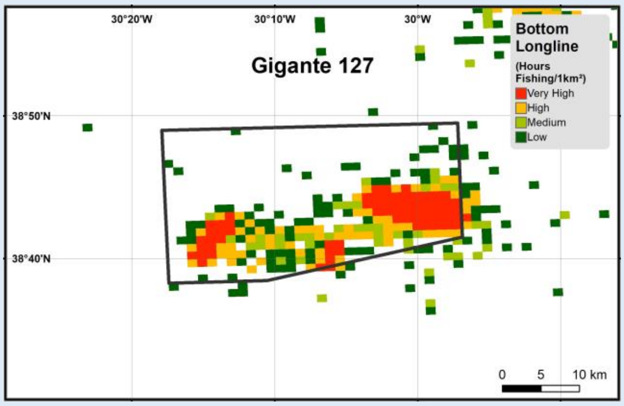
Existing regulations

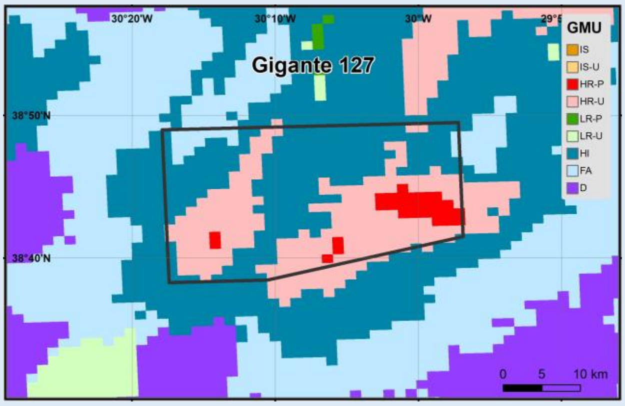
The Gigante SW & 127 complex lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nm from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

The Gigante SW & 127 seamount and ridge area is an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This seamount is occasionally visited by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and used regularly by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also visited this seamount.

Fishing intensity | Seabed Habitats



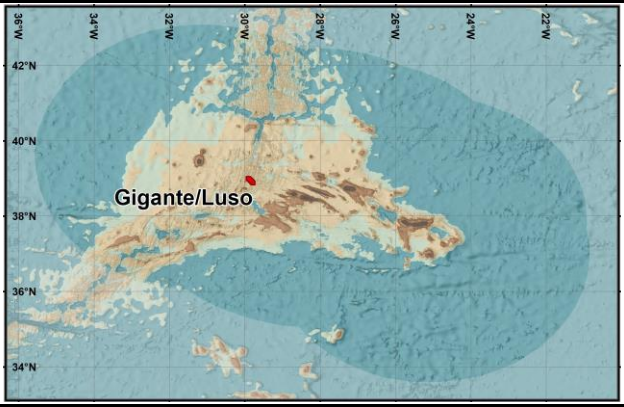


Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	4 dives with Luso ROV between 305-770 m depth, 10 dives with the drift-cam system between 180-540 m depth

Gigante / Luso

Cost model	AB + FB	**Area** (km)	350
Type	Seamount	**Depth range** (m)	165-1734
Code	I08	**Distance neighbour** (km)	8
Classification criteria	Important Area	**Bottom fishing effort** (%)	2.8
Main features	Known VME, shallow seamount, H. vent	**Existing MPAs**	Luso HV



Environmental setting

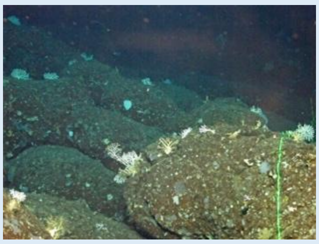
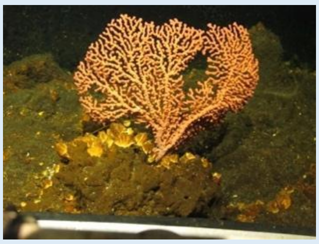
The Gigante seamount is located on the Mid-Atlantic Ridge, at around 39ºN and 30ºW, close to the triple junction of the North American, Nubian and Eurasian tectonic plates. It situated about 50 nm west of Faial Island and it is approximately 10 km long and 5 km wide. The seafloor ranges from 160 m to 1000 m depth, and reveals typical morphologies of a volcano produced by fissural volcanism associated with the central ridge. On June 16th 2018 a new hydrothermal vent was discovered and named Luso. This area is under the influence of a complex current system, which is still poorly known.

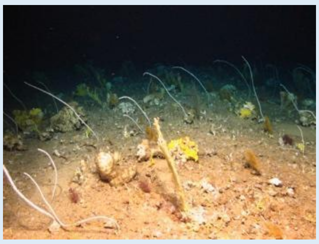
Biological benthic communities

The deepest zones host characteristic aggregations of *Narella versluysi* and *Narella bellissima*, with other octocorals (*Pleurocorallium johnsoni, Pseudoanthomastus* cf. *agaricus*) and sponges (cf. *Poecillastra compressa*, *Pheronema carpenteri*). When intact lava balloons appear, the community shifts to *Pleurocorallium johnsoni* and cf. *Poecillastra compressa*. At those depths, detritic beds are colonized by *Flabellum* species. Large crevices at 700 m host peculiar communities of *Placogorgia* sp. and caryophillids. At 600 m, rocky walls colonized by the deep-sea oyster cf. *Neopycnodonte zibrowii*. On the eastern flank, at 600 m, large *Paragorgia johnsoni* together with vent associated cirripeds become the most common aggregation. Hydrothermal vent fields found at 570 m, with diverse chemoautotrophic microbial communities but little associated megafauna. Above 550 m, coral species *Viminella flagellum* and *Acanthogorgia* cf. *hirsuta* dominate, together with the sponge cf. *Characella pachastrelloides* and black coral *Elatopathes abietina*. Above 400 m, large colonies of *Dentomuricea* aff. *meteor* and the sponge cf. *Leiodermatium pfeifferae* become common.

Images of benthic communities

Image credits: © ROV Luso/EMEPC / 2018 Oceano Azul Expedition



If a VME

This area contain the Luso hydrothermal vent. Presence of endemic species *Dentomuricea* aff. *meteor*. High diversity of species and communities. Dense coral gardens dominated by octocorals, particularly *Paragogia johnsoni* with large colonies (~1.5 m height) and endemic *Dentomuricea* aff. *meteor*. Larger corals are highly susceptible to fishing based on damaged colonies observed in video surveys. *Paragorgia* species have high longevity (~ 100 years) and slow growth rates. Shallow-water seamount, potentially a biodiversity hotspots of benthic and pelagic fauna.

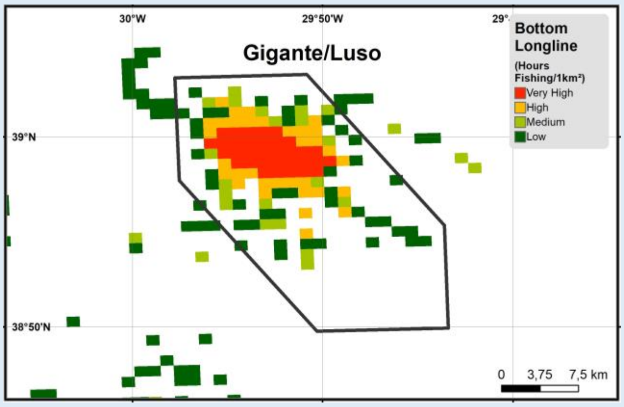
Existing regulations

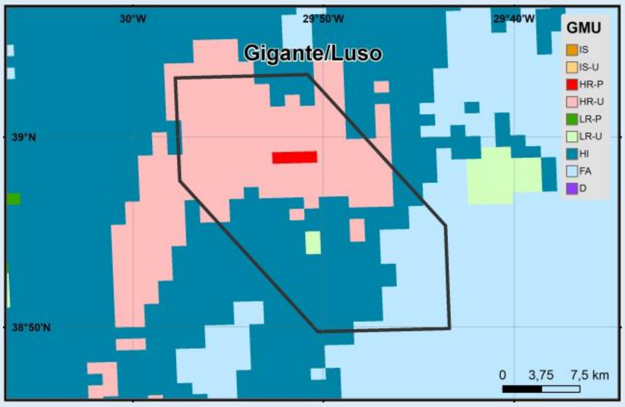
The Gigante seamount lies within the area for protection of deep-water corals from the effects of fishing; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation No. 1568/2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the islands shores and therefore fishing is restricted to vessels registered in Portugal (EC 1380/2013; in place until December 2022). An area around the Luso hydrothermal vent field is fully protected from fisheries since September 2019 (Portaria 68/2019). However, the regulation does not mention other activities and therefore deep-sea mining and scientific research were not subject to specific rules or prohibitions.

Human activities

The Gigante seamount is an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This seamount is also used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and occasionally visited by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also visited this area. This seamount has been an important area for open-ocean scientific research in the Azores.

Fishing intensity | Seabed Habitats





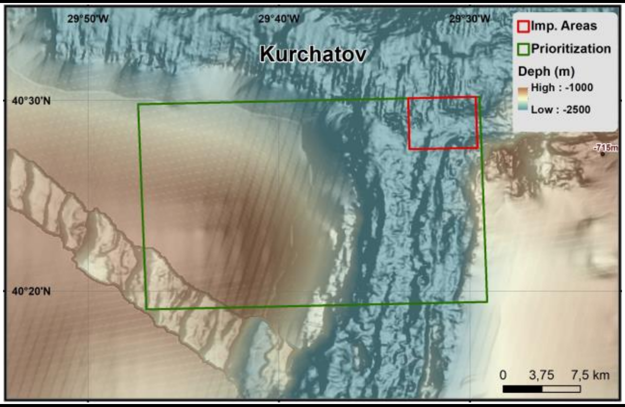
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	5 dives with Luso ROV between 230-825 m depth; 7 dives with the drift-cam system between 195-710 m depth

Kurchatov

Cost model	AB ≠ FS
Type	Fracture Zone
Code	I09
Classification criteria	Important area
Main features	Inferred H. vent

	AB	FS
Area (km)	405	505
Depth range (m)	569-3236	496-3233
Dist. neighbour (km)	49	49
Bottom fishing effort (%)	0.02	0.02
Existing MPAs	-	-



Environmental setting

The Kurchatov is the most relevant Fracture Zone in the Azores EEZ, north of the North Azores Fracture Zone at around 40.5°N. It literally divides the Mid Atlantic Ridge in two at this latitude. There have been little scientific surveys, but the area contains a large variety of habitats, such as the fracture zone valleys spreading both W/E and N/S, adjacent steep slopes or walls, small ridges and seamounts. The oceanography of this region is unknown but it is most likely to be very complex, with a high probability of enhanced currents in the deep valleys.

Biological benthic communities

The Kurchatov Fracture Zone area has never been surveyed using underwater video devices. However, the 1992 water column surveys conducted by OSU and IFREMER detected anomalies indicative of high-temperature hydrothermal activity at around (plume at 2150 m depth, bottom at 2970 m, FTU magnitude of 0.012). This region may also be an important transition zone regarding the distribution of the benthic communities along the MAR.

Images of benthic communities

There are currently no images available regarding the benthic habitats of this area.

If a VME

This area may contain hydrothermal vents associated with the MAR valley close to the Kruchatov Fracture Zone, since strong anomalies indicative of high-temperature hydrothermal activity were detected. Based on the precautionary principal, this areas was designated as a VME.

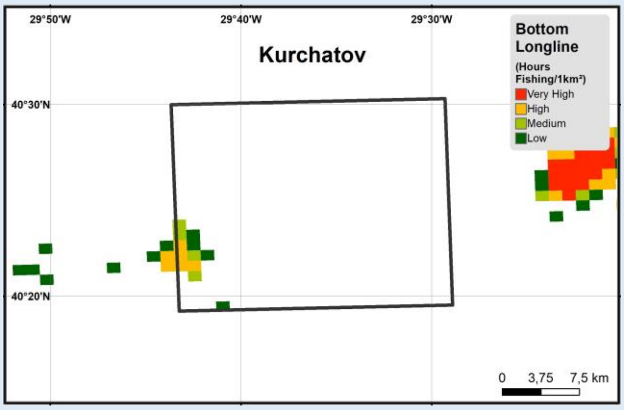
Existing regulations

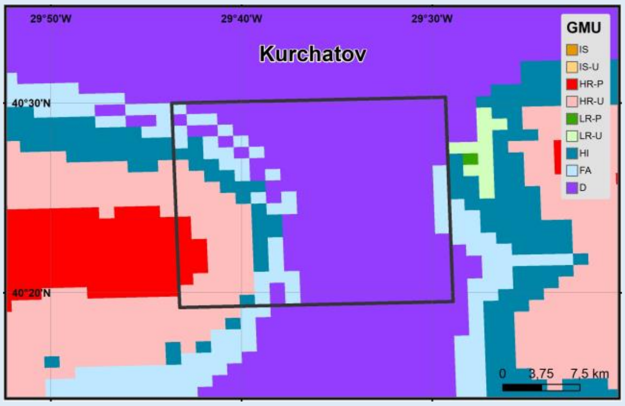
The Kurchatov area lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

The Kurchatov depression and fracture zone is deeper than the depths of operation of the local bottom longline fishing fleet. This area showed a certain overlap with the mainland Portugal pelagic longlining fleets targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*).

Fishing intensity / Seabed Habitats



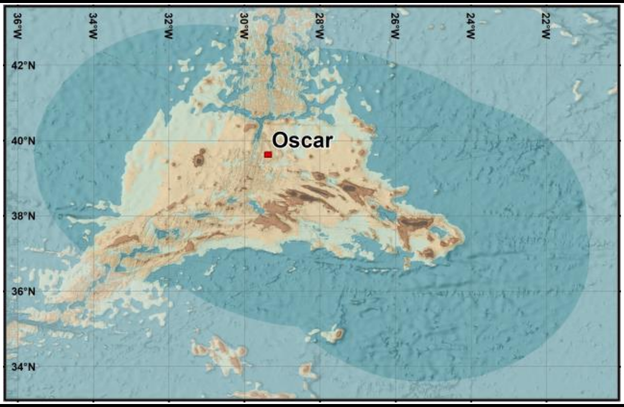


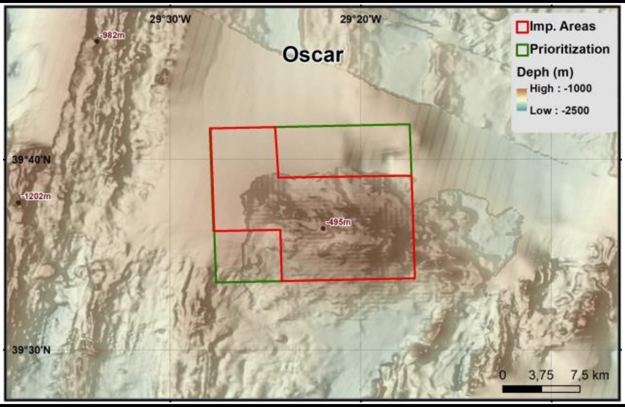
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Oscar seamount

Cost model	AB + FB	**Area** (km)	224
Type	Seamount	**Depth range** (m)	495-1672
Code	I10	**Distance neighbour** (km)	65
Classification criteria	Important Area	**Bottom fishing effort** (%)	2.6
Main features	Known VMEs	**Existing MPAs**	-





Environmental setting

Oscar seamount is located on the Mid-Atlantic Ridge, 65 nm north-west of Faial island. It is an elongated seamount with an E-W orientation, stretching for more than 15 km. It rises from below 1500 m to a depth of around 500 in the shallowest parts of the summit. Oscar seamount is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

The most discernable community of the upper part of this seamount corresponds to aggregations of the coral *Callogorgia verticillata*, with large colonies in patches that spread along several tens of meters. The association between *C. verticillata* and the primnoid corals *Narella bellissima* and *Narella versluysi* is also common, especially at depths of 650-700 m. In some hard substrates, aggregations of the yellow sea fan *Acanthogorgia* sp. can reach very high densities, as well as the association between the small white coral *Pleurocorallium johnsoni* and the yellow laminate sponge cf. *Poecillastra compressa*. This community displays a high number of accompanying species, such as the soft coral *Pseudoanthomastus* cf. *agaricus* and the black corals *Stichopathes* cf. *gravieri* and *Paranthipathes hirondelle.* Also on summit areas, whip corals of the species *Viminella flagellum* have been observed form aggregations with the large porifera cf. *Characella pachastrelloides* and *Craniella longipilis*. Deposits of coral rubble are common, but the cold-water coral species that have originated them still remain unclear.

Images of benthic communities

Image credits: © IMAR/OKEANOS-UAz, Drift camera

If a VME

Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of benthic communities. Dense coral gardens dominated by octocorals, particularly *Callogorgia verticillata* with large colonies (~1.5 m height) not seen in many other areas. *C. verticillata* has low growth rates and low reproductive output and is highly susceptible to fishing based on fisheries bycatch data.

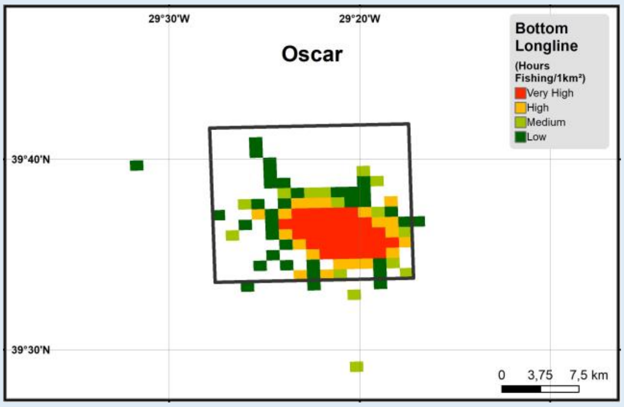
Existing regulations

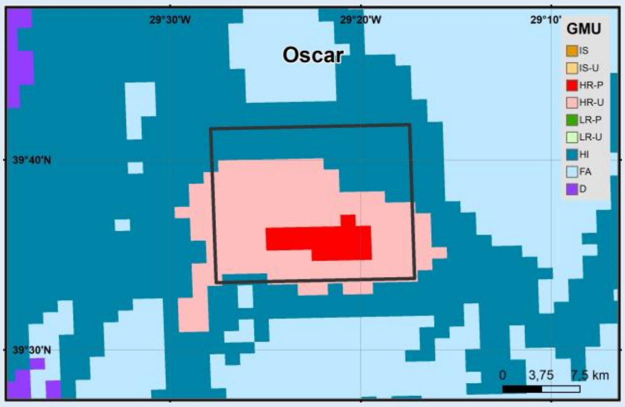
The Oscar seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

The Oscar seamount has become an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This seamount is occasionally visited by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g. *Prionace glauca*). The slopes of this seamount are used by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also visited this area.

Fishing intensity | Seabed Habitats



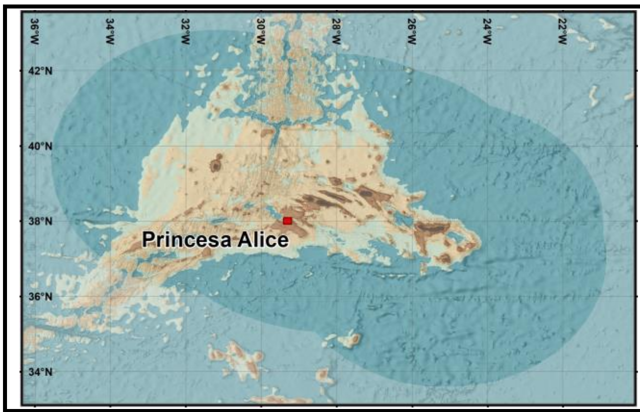


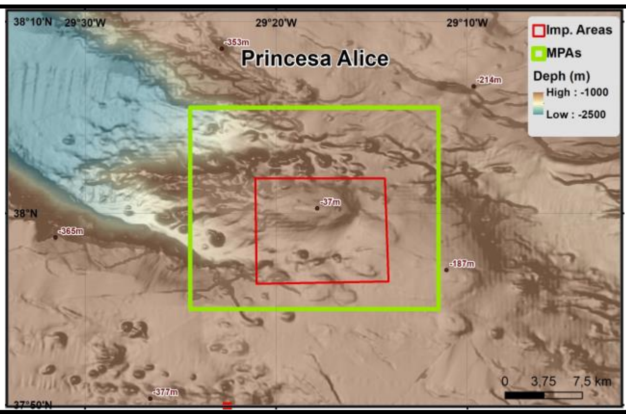
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	15 dives with the drift-cam system between 500-700 m depth

Princesa Alice bank

Cost model	AB + FS	**Area** (km)	370
Type	Seamount	**Depth range** (m)	37-2168
Code	I11	**Distance neighbour** (km)	11
Classification criteria	Important area	**Bottom fishing effort** (%)	4.1
Main features	Shallow seamount	**Existing MPAs**	PMA 15





Environmental setting

Princesa Alice bank is part of a large rifted oceanic plateau, located 40 nm south of Faial island. The inactive Princess Alice Rift divides this plateau into two distinct features: the Princesa Alice bank in the South and the Açor bank in the north. This bank, extending in a NW-SE direction, is about 70 km in length and roughly 25 km in width. The shallowest point on its steep summit reaches 30 m depth and the main plateau extends with very gentle slopes at about 600 m depth. This area is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

Banco Princesa Alice has never been explored with video surveying techniques. However, in the last decade, observers onboard fishing vessels have collected a large number of records of deep-sea benthic species accidentally by-caught during commercial operations and data is stored in the University of the Azores's biological reference collection COLETA. These records suggest that Banco Princesa Alice may host important deep-sea benthic communities, mostly composed of the Antipatharia species *Antipathella wollastoni* and *Tanacetipathes* in the photic areas (~40 m depth) of the seamount summit. Communities below 200 m depth show diverse assemblages of the octocorals *Callogorgia verticillata*, *Paracalypthrophora josephinae*, *Candidella imbricata*, *Acanthogorgia armata, Viminella flagellum*, the scleractinians *Dendrophylia cornigera*, *Caryophyllia* spp., *Desmophyllum dianthus*, antipatharians *Leiopathes glaberrima* and the stylasterid *Errina dabneyi*. Unidentified sponges were also frequently recorded.

Images of benthic communities

No images are currently available for the deep-sea areas of the Princesa Alice bank.

If a VME

Although not all seamounts are the same, shallow-water seamounts (with summits shallower of approximately 250 m depth) may be considered important areas because of the communities they host, their ecological role for demersal fish, and their resilience potential towards climate change. These seamounts have often been nominated as biodiversity hotspots not only for the benthic fauna but also for the large megafauna that visits these features.

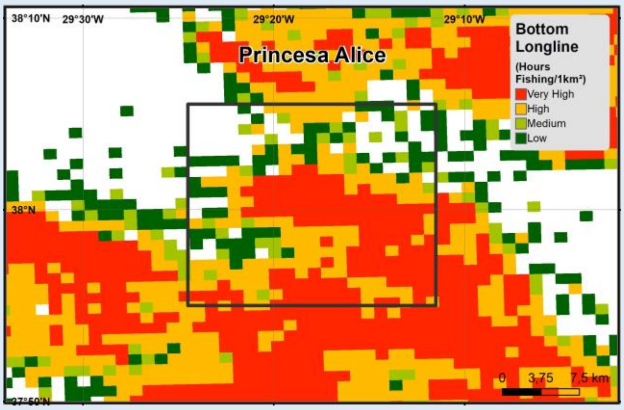
Existing regulations

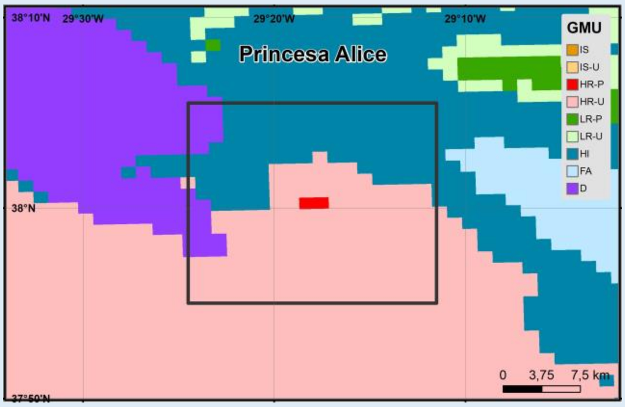
The summit of the Princesa Alice bank (PMA 15) is a marine protected area for resource management (IUCN VI) and included in the Azores Marine Park, but lacks effective protection measures (DLR 13/2016/A). This area lies within the area for protection of deep-water corals from the effects of fishing; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation No. 1568/2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. Princesa Alice bank lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

The Princesa Alice bank is probably the most important fishing ground of the Azores. The area identified here as a priority area overlaps with the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This area is also highly used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also visited this area. This seamount has been an important area for tourism activities and for open-ocean scientific research in the Azores.

Fishing intensity — Seabed Habitats



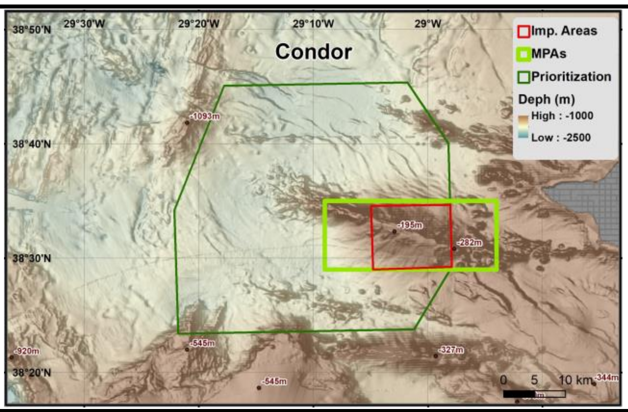


Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Condor

Cost model	AB + FB	**Area** (km)	1278
Type	Seamount	**Depth range** (m)	185-2035
Code	I12	**Distance neighbour** (km)	8
Classification criteria	Important Area	**Bottom fishing effort** (%)	0.2
Main features	Known VME, shallow seamount	**Existing MPAs**	PMA 14, Fishing closure



Environmental setting

Condor is an elongated volcanic seamount located 17 km southwest of Faial Island. Its ridge extends NW-SE for 39 km, with its shallowest point on its flat summit at 185 m depth and its flanks extending with gentle slopes down to 2000 m depth. The oceanographic conditions over Condor are different from the surrounding environment, mainly characterized as enclosed circulation around the seamount, and pronounced mixing most probably due to semidiurnal tidal effects.

Biological benthic communities

Coral gardens formed by the octocorals *Viminella flagellum*, *Dentomuricea* aff. *meteor* and *Callogorgia verticillata*, together with the large hydrozoan cf. *Lytocarpia myriophyllum,* dominate the summit of Condor. Also at the summit, aggregations of the hexactinellid sponge *Asconema* sp. and patches of the scleractinian coral genus *Eguchipsammia* have also been observed. Coarser substrates on the flanks are generally dominated by lithistid sponges, replacing gorgonian corals as depth increases. Also on the flanks, aggregations of the hexactinellid sponge *Pheronema carpenteri* have been observed, generally of a limited extension. On the southern side, gorgonians of the genus *Acanthogorgia* are found in combination with the laminate sponge cf. *Pachastrella monilifera*, whilst coral gardens formed by of the white gorgonian *Candidella imbricata* can be observed in the deepest part of the seamount, in most cases accompanied by the yellow cup coral *Leptopsammia formosa*. Sandy patches on the lower slopes are colonized by the foraminifera cf. *Syringammina fragillissima*.

Images of benthic communities

Image credits: © IMAR/UAç, MIDAS project




If a VME

Populations of endemic species *Dentomuricea* aff. *meteor* and CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*. High diversity of species and communities. Mixed coral gardens composed of several octocoral species and sponge aggregations. Slow growing, long-lived species susceptible to fishing based on bycatch data. Reefs of *E. cornucopia*, a species not known to form reefs elsewhere in the Atlantic and to represent a potential relict species from geological past. Shallow-water seamount, potentially a hotspot of biodiversity of benthic and pelagic fauna and an important area for scientific research.

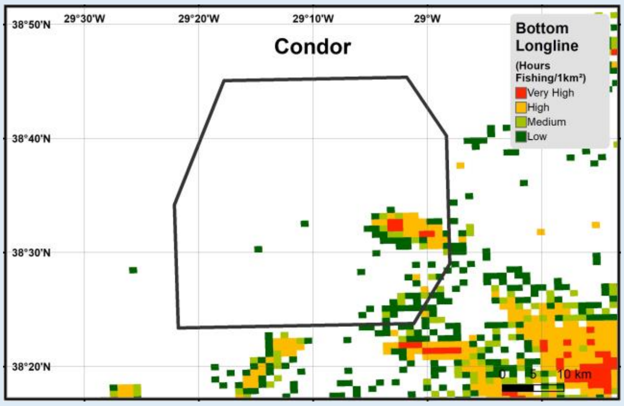
Existing regulations

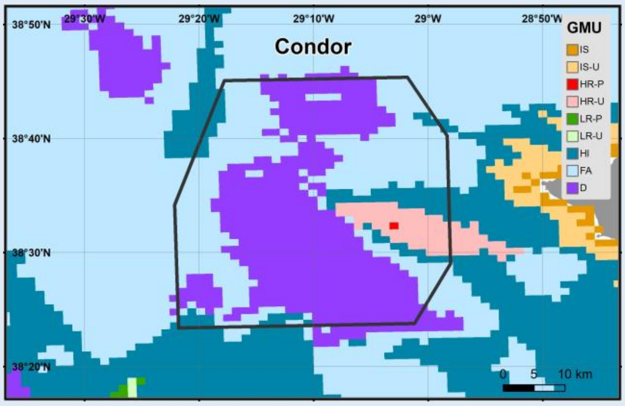
The Condor seamounts (PMA 14) is marine protected areas for resource management (IUCN VI) under the Azores Marine Park but lack effective protection measures (DLR 13/2016/A). However, the Condor seamount is closed to bottom fishing for research purposes (Portaria 48/2010) since 2010 but its regulation ends in 2020 (Portaria 94/2017). This area lies within the area for protection of deep-water corals from the effects of fishing; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation No. 1568/2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 metres. Condor seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

The Condor seamount has been a traditional fishing ground for the Azorean bottom longline and handline fleet since 1962, when the tuna vessel "Condor" discovered and named the seamount. This area is temporally closed to bottom fishing. This area was described as hosting exceptional abundances of fish, mainly referring to wreckfish (*Polyprion americanus*) and blackspot seabream (*Pagellus bogaraveo*). This area was also used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also visited this area. This seamount has been an important area for tourism activities and for open-ocean scientific research in the Azores.

Fishing intensity **Seabed Habitats**



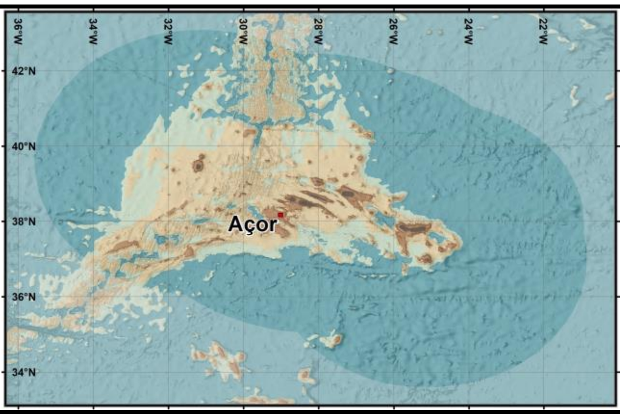


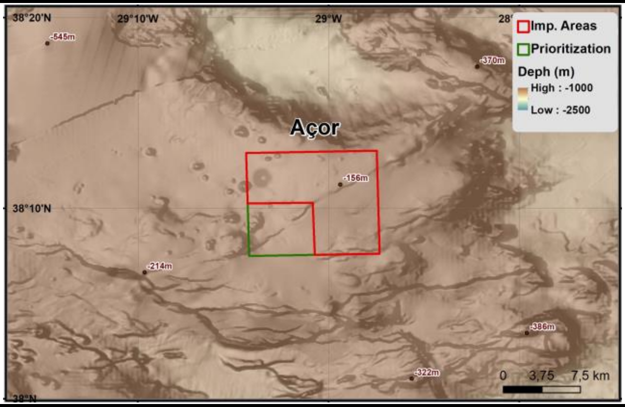
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	15 Hopper dives between 240-1100 m

Açor bank

Cost model	AB + FS	**Area** (km)	100
Type	Seamount	**Depth range** (m)	158-602
Code	I13	**Distance neighbour** (km)	11
Classification criteria	Important area	**Bottom fishing effort** (%)	2.4
Main features	Shallow seamount	**Existing MPAs**	-





Environmental setting

Açor bank is part of a large rifted oceanic plateau, located 20 nm south of Faial island. The inactive Princess Alice Rift divides this plateau into two distinct features: the Açor bank in the north and the Princesa Alice bank in the South. The Açor bank, extending in a NW-SE direction, is about 85 km in length and roughly 20 km in width. The shallowest point on its summit reaches 180 m depth and the main plateau extends with very gentle slopes, but with some steep walls, at about 700 m depth. This area is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water.

Biological benthic communities

Banco Açor was visited by ROV in 2010 but surveys covered only a small portion of the south and west flanks of the seamount. Large accumulations of coral rubble mostly formed by dead *Madrepora oculata* and *Lophelia pertusa* were found at the base of the seamount at 900 m depth. Radiocarbon dating of these coral remains revealed that corals died 11,000 years ago during the last deglaciation period. Other benthic communities found included large aggregations of the glass sponge *Pheronema carpenteri* at 900 m depth and the stylasterid *Errina dabneyi* at 500 m depth. However, records of deep-sea benthic species accidentally by-caught during commercial operations and stored in the University of the Azores's biological reference collection COLETA, reveal the presence of large sized octocorals such as *Callogorgia verticillata* and *Paracalypthrophora josephinae* and the antipatharian *Leiopathes glaberrima*.

Images of benthic communities

If a VME

Although not all seamounts are the same, shallow-water seamounts (with summits shallower of approximately 250 m depth) may be considered important areas because of the communities they host, their ecological role for demersal fish, and their resilience potential towards climate change. These seamounts have often been nominated as biodiversity hotspots not only for the benthic fauna but also for the large megafauna that visits these features.

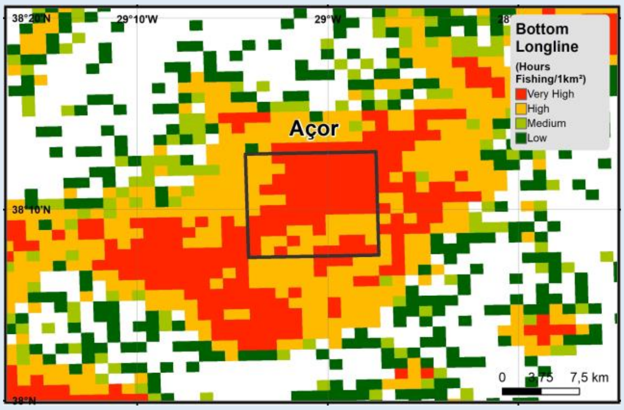
Existing regulations

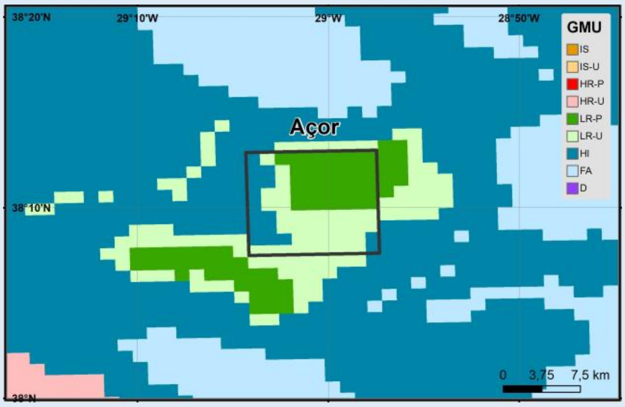
The Açor bank lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

The Açor bank (connected to the Princesa Alice bank) is also one of the most important fishing ground of the Azores. The small area identified here overlaps with the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This area is also used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also visited this area.

Fishing intensity — Seabed Habitats



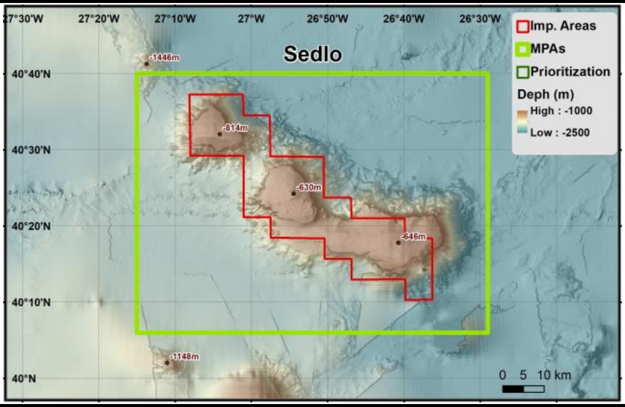


Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	2 dives with ROV Luso between 200-920 m depth

Sedlo seamount

Cost model	AB + FS	**Area** (km)	4093
Type	Seamount	**Depth range** (m)	489-2918
Code	I14	**Distance neighbour** (km)	69
Classification criteria	Important area	**Bottom fishing effort** (%)	0.5
Main features	Essential fish habitat	**Existing MPAs**	PMA 05



Environmental setting

Sedlo seamount is located 90 nautical miles north-east of Graciosa and North of Terceira islands. Sedlo is an isolated seamount that rises steeply from a depth of around 2000 m, with its shallowest peak at around 600 m depth. The whole seamount has an elongated shape and stretches for 75 km, but it displays 3 very discernable flat-top structures, a type of geomorphology not very common in the Azores region. The tablemount shape of this massif indicates that its summit was once located above sea level and was abraded by oceanic swells before subsiding considerably. Studies on water current dynamics suggest the existence of an enclosed circulation cell around each peak.

Biological benthic communities

The summit and slope are mostly of a rock nature, with several areas of cobbles and boulders, and patches of biogenic sediment. The benthic community is generally dominated by anemones, corals and sponges. The diversity of corals and sponges is particularly high in the saddle and gully between the two eastern peaks, and dense aggregations of soft corals can be found in certain areas. Octocorals are especially abundant on the southwest side, at a depth of 1700 m, where brittle stars are also present. The base of the seamount is almost exclusively covered in fine sediments, with low faunal abundances.

Images of benthic communities

There are currently no images available regarding the benthic habitats of this seamount.

If a VME

Experimental fishing surveys undertaken (2001-2002) identified Sedlo as an important reproductive area for orange roughy (*Hoplostethus atlanticus*), slender alfonsino (*Beryx splendens*) and cardinal fish (*Epigonus telescopus*), and was designated as an Essential Fish Habitat for some deep-water fishes in the Azores.

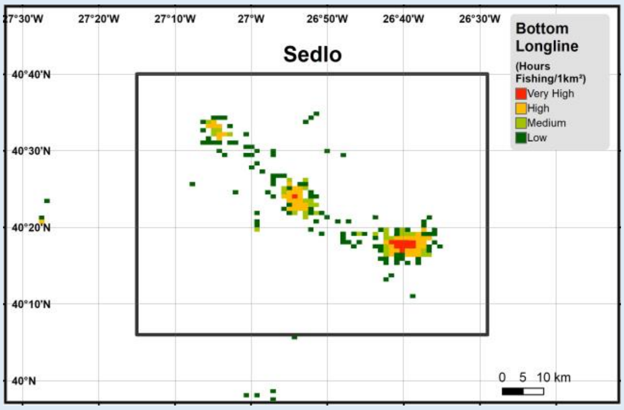
Existing regulations

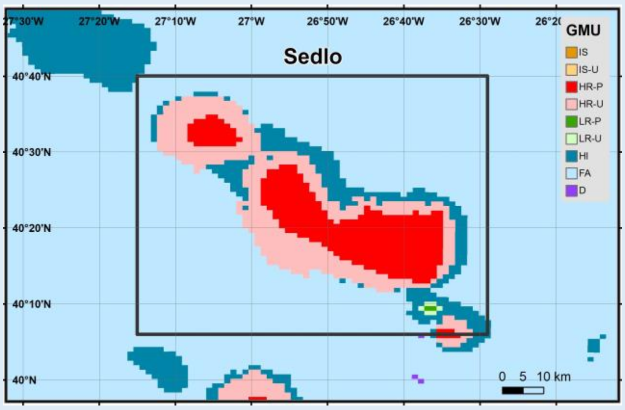
The Sedlo seamount (PMA 05) is a Nature Reserve (IUCN, Category I) with restrictions to all types of fishing gears (except epipelagic fishing), deep-sea mining, dumping and other activities that may cause harm to the marine environment (DLR 13/2016/A). This area lies within the area for protection of deep-water corals from the effects of fishing; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation No. 1568/2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. Half of Sedlo seamount lies within 100 nautical miles from the island shores and therefore fishing is restricted to vessels registered in Portugal (EC 1380/2013; in place until December 2022).

Human activities

Sedlo seamount was an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This area is also used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) but not visited very often by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also visited this area. This seamount has been an important area for scientific research in the Azores.

Fishing intensity | Seabed Habitats





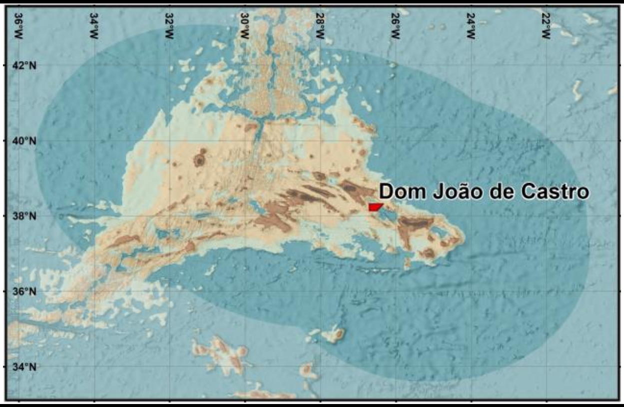
Scientific knowledge

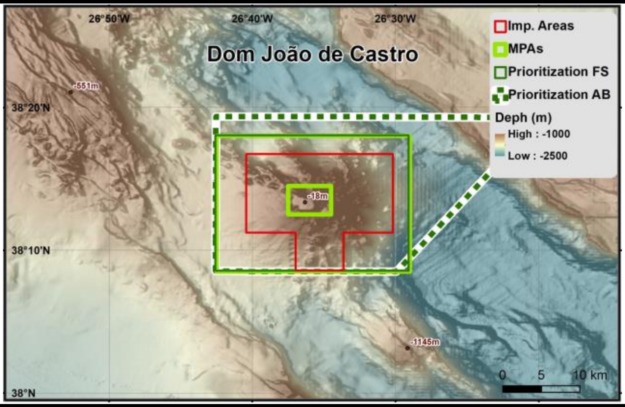
Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Dom João de Castro

Cost model	AB ≠ FS
Type	Seamount
Code	I15
Classification criteria	Important area
Main features	Known VME, shallow smt, H. vent

	AB	FS
Area (km)	517	346
Depth range (m)	18-2749	18-2797
Dist. neighbour (km)	70	37
Bottom fishing effort (%)	0.4	0.4
Existing MPAs	PMA 01, PMA 11	





Environmental setting

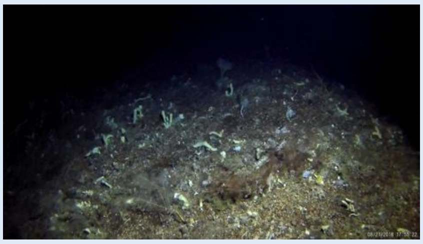
Dom João de Castro is a volcanic seamount located between the islands of Terceira and São Miguel, on the hyperslow-spreading Terceira rift. This seamount was formed after a volcanic eruption that occurred in 1720, generating a small island of 150 m height. Erosional processes made the island disappear, and the top of the seamount is currently found below sea surface, at 13 m depth. The seamount summit is characterized by exuberant hydrothermal activity at shallow and intermediate depths. This area is likely under the influence of the North Atlantic Central Water and the Northern Sub-Polar Water, but might be also be under the influence of the Mediterranean Outflow Water.

Biological benthic communities

Rocky outcrops on the deepest part explored, at around 500 m depth, are dominated by the white coral *Pleurocorallium johnsoni*, accompanied by the soft coral *Pseudoanthomastus* cf. *agaricus*. In contrast, the composition of the benthic communities dwelling between 300 and 450 m depth is dominated by the primnoid *Callorgorgia verticillata* found forming relatively dense aggregations with some very large colonies. The whip coral *Viminella flagellum* and the large hydrozoan cf. *Lytocarpia myriophyllum* can also be observed as accompanying species, but never forming dense patches. In the shallower areas of the summit, the mixed substrates have a very different species composition, with a large number of small Porifera, such as cf. *Petrosia crassa* and *Leiodermatium* spp.

Images of benthic communities

Image credits: © IMAR/OKEANOS-UAz, Drift camera



If a VME

Dom João de Castro contain hydrothermal vents and species with amphi-Atlantic or Atlanto-Mediterranean distribution. Dense coral gardens dominated by octocorals, particularly *Callogorgia verticillata,* with the presence of many large colonies. Few signs of fishing impacts. Shallow-water seamount, potentially a biodiversity hotspots for benthic and pelagic fauna.

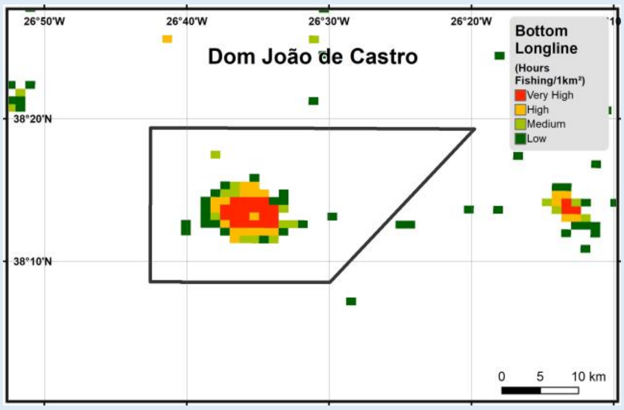
Existing regulations

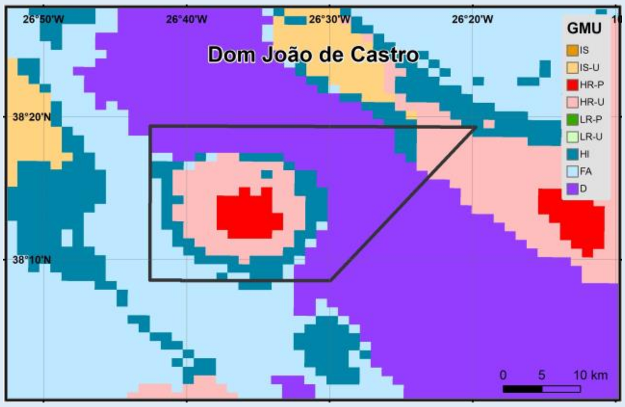
The summit of the Don João de Castro seamount is a small Marine Natural Reserve (IUCN category I) that encompasses a shallow-water venting system and is included in the Azores Marine Park (PMA 01). In this area, fisheries restrictions apply to all types of gears (except epipelagic fishing), deep-sea mining, dumping and other activities that may cause harm to the marine environment. The wider Don João de Castro seamount is a marine protected area for resource management (IUCN VI) and included in the Azores Marine Park (PMA 11) but lack effective protection measures under this regulation (DLR 13/2016/A). This area lies within the area for protection of deep-water corals from the effects of fishing; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation No. 1568/2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. Don João de Castro bank lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

D. João de Castro seamount is a small but important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other demersal fishes. This seamount is also highly used by the local pole-and-line fleet targeting tuna species and regularly visited by the mainland Portugal pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g. *Prionace glauca*). Due to its shallow depths, this seamount has been an important area for scientific research and is sporadically visited by tourism companies.

Fishing intensity — Seabed Habitats



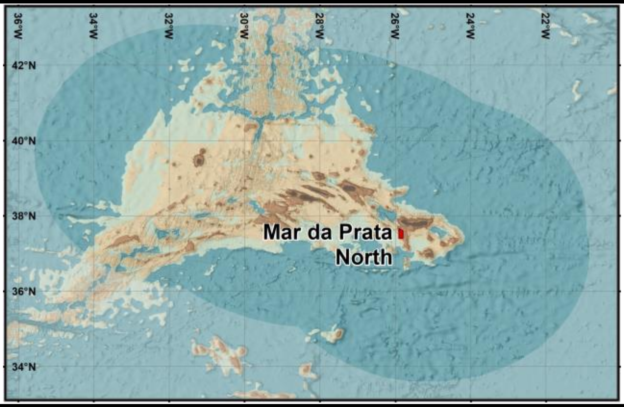


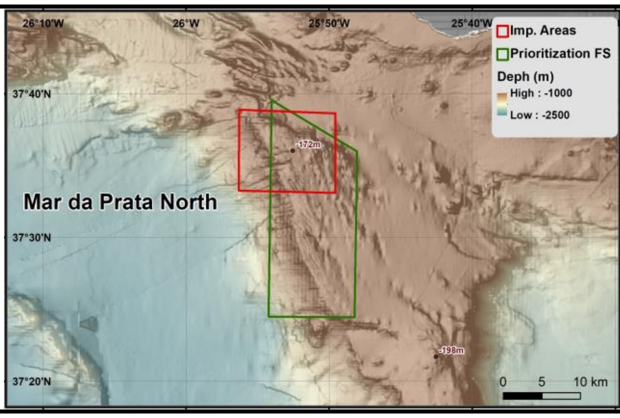
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	5 dives with the drift-cam system between 220-475 m depth

Mar da Prata North

Cost model	AB + FB	**Area** (km)	218
Type	Ridge like seamount	**Depth range** (m)	172-2130
Code	I16	**Distance neighbour** (km)	6
Classification criteria	Important Area	**Bottom fishing effort** (%)	1.0
Main features	Known VME, shallow seamount	**Existing MPAs**	-





Environmental setting

Mar da Prata (a.k.a. Monaco Spur) is an elongated seamount located in the Eastern group of the Azores EEZ, between the islands of São Miguel and Santa Maria. The edges of the North peak of Mar da Prata are located in the Azores microplate, about 10 nm south of São Miguel and 30 nm North of Santa Maria. This region is likely under the influence of the North Atlantic Central Water and may be reached by the Mediterranean Outflow Water.

Biological benthic communities

A small part of the summit in the vicinity of the area selected for Mar da Prata North was visited by the EMEPC with the ROV Luso in 2009. The soft bottom grounds are mainly colonized by small sponge species, with the dominance of (most likely) the laminate cf. *Phakellia ventilabrum* and some large cf. *Neophrisospongia nolitangiere* and cf. *Petrosia crassa*. When the rock outcrops, the community is characterized by the presence of several octocoral species that coexists in the same area, including *Acanthogorgia* spp., *Dentomuricea* aff. *meteor* and *Callogorgia verticillata,* together with several encrusting and erect sponges. The abundance of the yellow sea fans of the genus *Acanthogorgia* is much larger than that of the other species, in some areas attaining relatively high numbers. The association between the whip coral *Viminella flagellum* and the large sponge cf. *Characella pachastrelloides* was also observed on hard grounds.

Images of benthic communities

Image credits: © ROV Luso / EMPEC

If a VME

Although not all seamounts are the same, shallow-water seamounts (with summits shallower of approximately 250m depth) may be considered important areas because of the communities they host, their ecological role for demersal fish, and their resilience potential towards climate change. These seamounts have often been nominated as biodiversity hotspots not only for the benthic fauna but also for the large megafauna that visits these features.

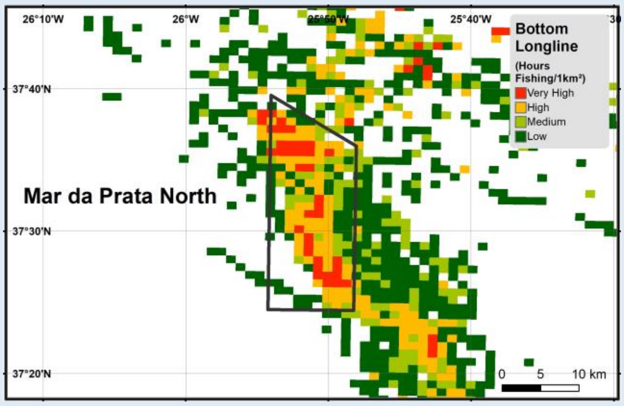
Existing regulations

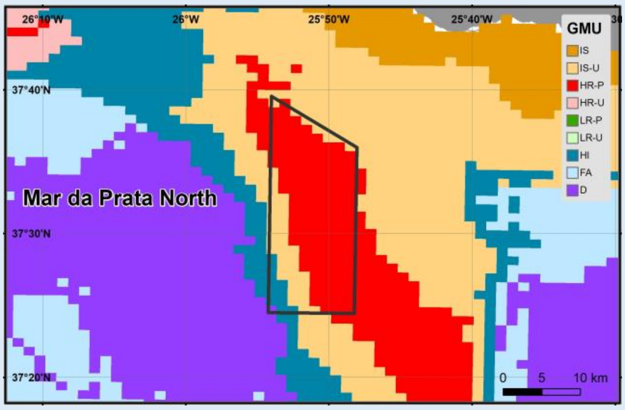
The North peak of Mar da Prata seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

The North peak of Mar da Prata seamount used to be an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This seamount is also used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and occasionally visited by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also sporadically visited this seamount.

Fishing intensity / Seabed Habitats



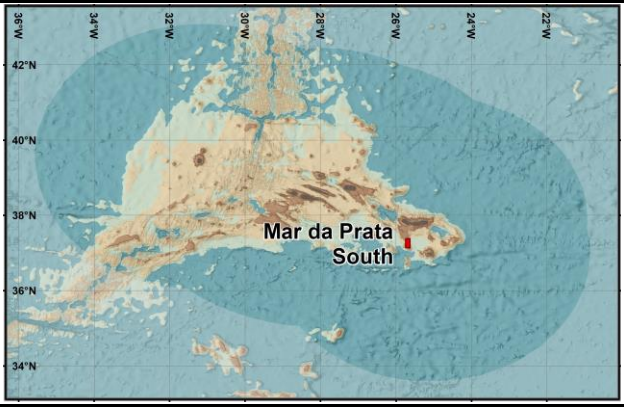


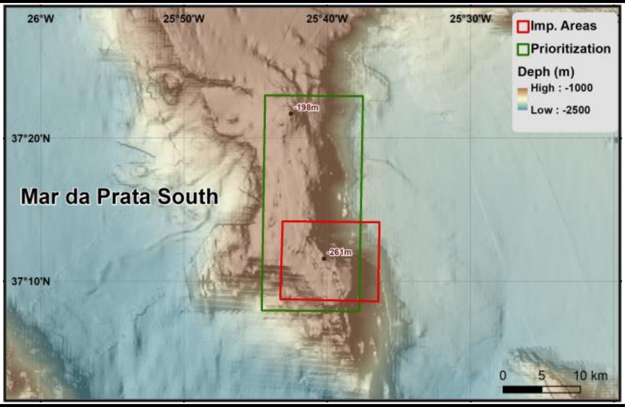
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	2 dives with ROV Luso between 420-310 m depth

Mar da Prata South

Cost model	AB + FB	**Area** (km)	280
Type	Ridge like seamount	**Depth range** (m)	198-1993
Code	I17	**Distance neighbour** (km)	6
Classification criteria	Important Area	**Bottom fishing effort** (%)	0.8
Main features	Shallow seamount	**Existing MPAs**	-





Environmental setting

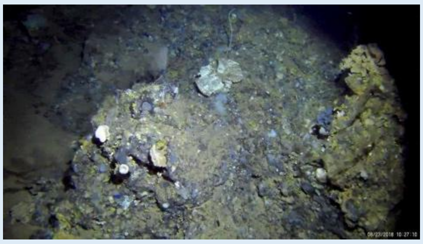
Mar da Prata (a.k.a. Monaco Spur) is an elongated seamount located in the Eastern group of the Azores EEZ, between the islands of São Miguel and Santa Maria. The edges of the south peak of Mar da Prata are located in the Azores microplate, about 20 nm south of São Miguel and north of Santa Maria. This region is likely under the influence of the North Atlantic Central Water and may be reached by the Mediterranean Outflow Water.

Biological benthic communities

The flat areas of the summit are characterized by sand and fine gravels, with very little invertebrate fauna reported so far. When boulders and rocks start to appear, the community is characterized by several lithistid sponges, some of which of relatively large sizes. Common Porifera include *Leiodermatium lynceus* and *L. pfeifferae*, cf. *Macandrewia azorica* and cf. *Petrosia crassa*. The mixed substrates of the summit of Mar da Prata host populations of the whip coral *Viminella flagellum*, until now observed as scattered colonies and low density patches. Conversely, on the southeastern side of the mound, the hard substrates of the upper slopes host a very well-structured community characterized by the yellow sea fan *Dentomuricea* aff. *meteor* in very high densities, accompanied by *V. flagellum*.

Images of benthic communities

Image credits: © IMAR/OKEANOS-UAz, Drift camera



If a VME

Presence of endemic species *Dentomuricea* aff. *meteor*. Dense coral gardens dominated by octocorals and diverse sponge aggregations but covering a small area. Evidence of fishing impacts. Shallow-water seamount, potentially a biodiversity hotspot of benthic and pelagic fauna.

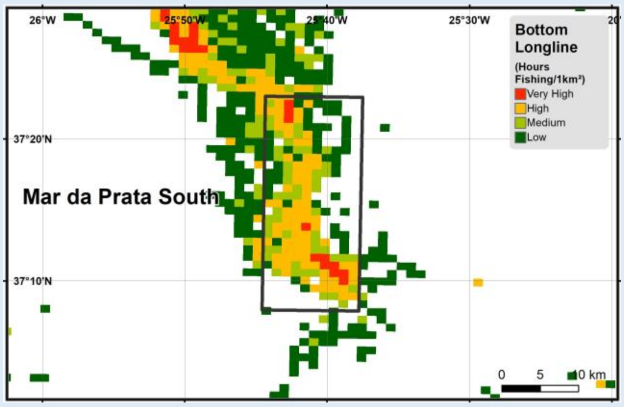
Existing regulations

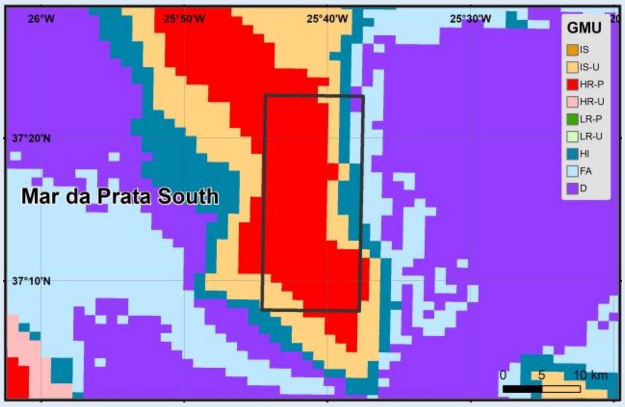
The south peak of Mar da Prata seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

The south peak of Mar da Prata seamount used to be an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This seamount is also used by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*) and occasionally visited by the local pole-and-line fleet targeting tuna species. The pelagic longlining fleets from mainland Portugal also sporadically visited this seamount.

Fishing intensity | Seabed Habitats





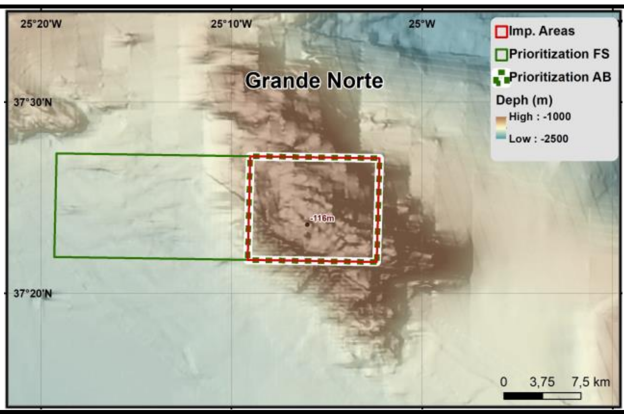
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	3 dives with the drift-cam system

Grande Norte

Cost model	AB≠FS
Type	Seamount & plain
Code	I18
Classification criteria	Important area
Main features	Shallow seamount

	AB	FS
Area (km)	100	250
Depth range (m)	117-1764	117-2059
Dist. neighbour (km)	14	14
Bottom fishing effort (%)	0.2	0.2
Existing MPAs	-	-



Environmental setting

Grande Norte is a point source volcanic seamount located about 20 nm South of São Miguel island, 23 nm North of Santa Maria, and about 20 nm NW of Formigas bank. This seamount extends roughly NW-SE for approx. 20 km, with its shallowest point at about 120 m depth and its flanks extending with gentle slopes down to 1500 m depth. The oceanography of this area is unknown but since it represents one of the first seamounts in the Azores to be along the path of the Mediterranean Outflow Water (MOW), its faunistic composition might be influenced by such a particular oceanographic setting.

Biological benthic communities

There is currently no information available regarding the composition and structure of the benthic communities present in this seamount.

Images of benthic communities

There are currently no images available regarding the benthic habitats of this seamount.

If a VME

Although not all seamounts are the same, shallow-water seamounts (with summits shallower of approximately 250 m depth) may be considered important areas because of the communities they host, their ecological role for demersal fish, and their resilience potential towards climate change. These seamounts have often been nominated as biodiversity hotspots not only for the benthic fauna but also for the large megafauna that visits these features.

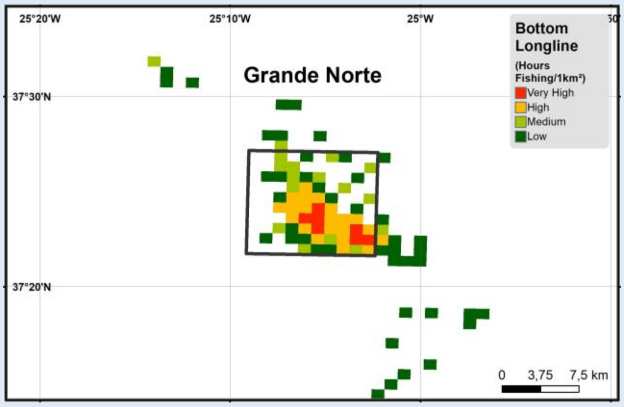
Existing regulations

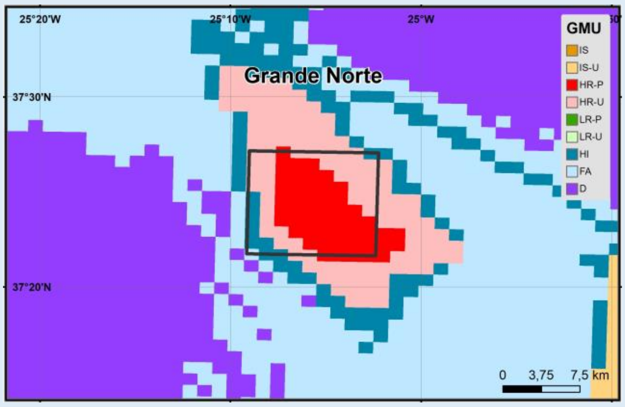
The Grande Norte seamount lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This seamount lies within 100 nautical miles from the baselines of the Union outermost regions and therefore fishing is restricted to vessels registered in the ports of those territories (EC 1380/2013; in place until December 2022).

Human activities

Grande Norte seamount used to be a small but important fishing ground for the bottom longline fleet from São Miguel and Santa Maria islands, targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This seamount is also highly used by the local pole-and-line fleet targeting tuna species and occasionally visited by the local pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*).

Fishing intensity / Seabed Habitats





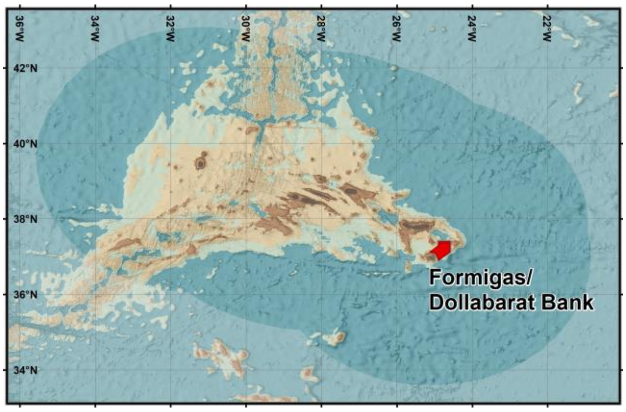
Scientific knowledge

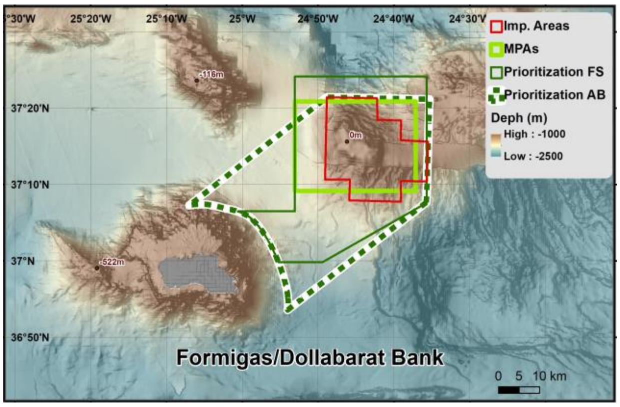
Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Formigas and Dollabarat

Cost model	AB ≠ FS
Type	Seamount & plain
Code	I19
Classification criteria	Important area
Main features	Known VME, shallow seamount

	AB	FS
Area (km)	1277	1085
Depth range (m)	0-2422	0-2484
Dist. neighbour (km)	14	
Bottom fishing effort (%)	0.02	
Existing MPAs	SMA01	





Environmental setting

The Formigas and Dollabarat seamount is located 34 nm south-west of São Miguel, in the easternmost part of the Terceira Rift, at the western end of the Eurasian–Nubian plate boundary. It rises from abyssal depths to the surface (1800-10 m), including a small set of islets. The bank lies in NW-SE direction, the western side of the seamount being steeper than the eastern side. The bank is not entirely volcanic, with some calcareus fosiliferus outcrops. This is first seamount in the Azores to be along the path of the Mediterranean Outflow Water (MOW), and hence it could influence its faunistic composition.

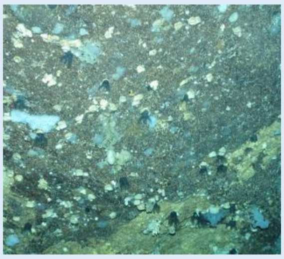
Biological benthic communities

The deepest areas are mostly flat and sedimentary, with scattered sea urchins cf. *Cidaris cidaris* and the octocoral *Acanella arbuscula*. When the rock outcrops, the number of species increases rapidly, leading to a diverse mixed community of octocorals, black corals and sponges (with large *Leiopathes expansa*). Some alive colonies of the scleractinians *Lophelia pertusa* and *Desmophyllum dianthus* were observed in low numbers. Around 1200 m depth, in an area of compact soft sediments, large aggregations of the lollypop sponge *Stylocordyla pellita* were found. At 1000 m, the octocoral *Candidella imbricata* becomes very common, together with *Hemicorallium niobe*. At around 900 m depth, the 'living-fossil community' of the crinoid cf. *Cyathidium foresti* can also be identified, together with several brachiopods and encrusting and hexactinellid sponges. The shallowest areas (800-650 m) host a community characterized by the primnoids *Narella versluysi* and *Narella bellissima*, associated to a wide array of species.

Images of benthic communities

Image credits: © MEDWAVES, ATLAS project



If a VME

Presence of CITES listed black coral *Leiopathes* sp. High diversity of species and communities. Dense coral gardens dominated by octocorals and black corals, and diverse sponge aggregations. Millenia-old black coral *Leiopathes.* Communities generally well preserved, showing little impacts from fishing. Shallow-water seamount, potentially a biodiversity hotspots for benthic and pelagic fauna.

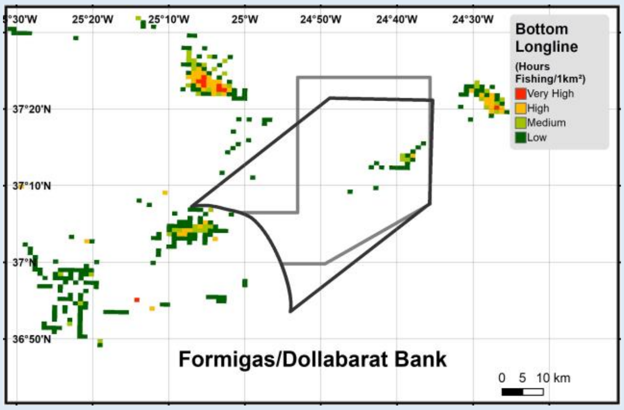
Existing regulations

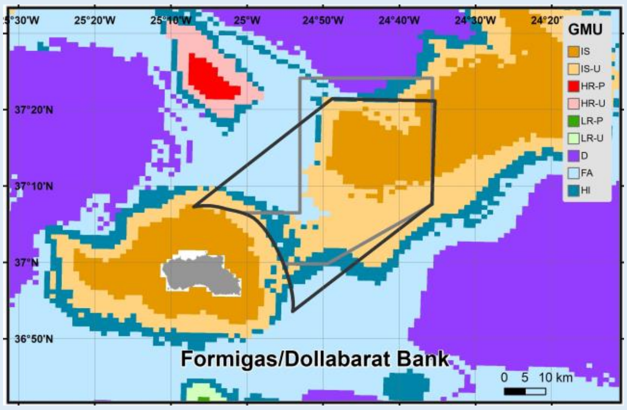
The Formigas and Dollabarat seamount is a Marine Reserve (SMA01, IUCN category I) regulated under the Santa Maria Island Natural Park (Decreto Legislativo Regional n.º 39/2012/A), with restrictions to all types of fishing gears with exception of the handlines or pole-and-line fishing for tuna species (DLR n.º 39/2012/A). This area lies within the area for protection of deep-water corals from the effects of fishing; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation No. 1568/2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. Formigas and Dollabarat seamount lies within 100 nautical miles from the island shores and fishing is restricted to vessels registered in Portugal (EC 1380/2013; in place until December 2022).

Human activities

Formigas and Dollabarat seamount used to be a small but important fishing ground for the local bottom longline fleet, but has been closed to bottom fishing since 1980s. There are evidences of illegal bottom fishing occurring in the area. In recent years, the Formigas and Dollabarat area has been an important fishing ground for the local pole-and-line fleet targeting tuna species. Due to its shallow depths, this area has been an important area for scientific research and for tourism activities.

Fishing intensity — Seabed Habitats





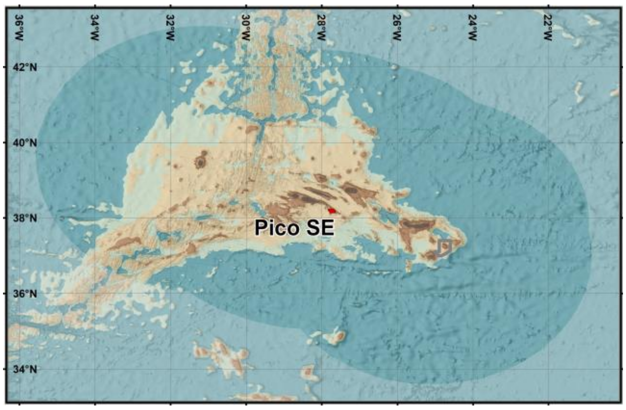
Scientific knowledge

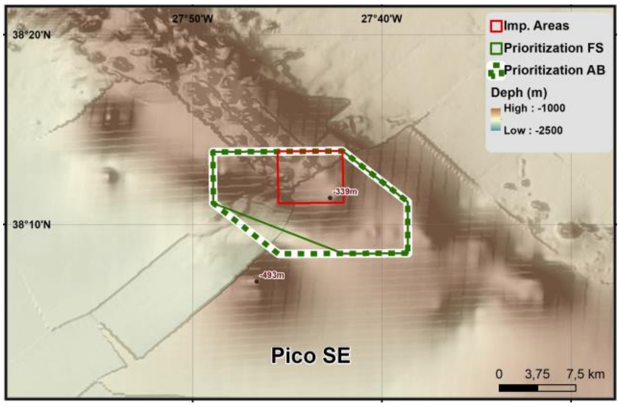
Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	10 dives with Liropus ROV between 500-1575 m depth

Pico SE

Cost model	AB ≠ FS
Type	Seamounts
Code	I20
Classification criteria	Important area
Main features	Known VME

	AB	FS
Area (km)	125	112
Depth range (m)	161-1713	161-1612
Dist. neighbour (km)	30	40
Bottom fishing effort (%)	1.3	1.3
Existing MPAs	-	-





Environmental setting

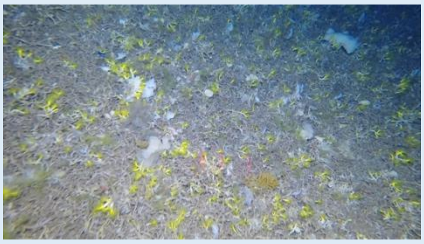
This area is located in the easternmost region of the Pico Island, along the Fail-Pico Fracture zone. It is composed of several cones of volcanic origin with a NW-SE orientation. The priority area is located in the SE portion of this geological structure encompassing only a small portion of it. The oceanographic conditions over this region are poorly known but might be characterized by strong currents and pronounced mixing.

Biological benthic communities

The volcanic cones SE of Pico host very diverse and structurally complex habitats. The summits and upper slopes are generally dominated by several species of corals, whose abundances vary across and within mounds. The yellow sea fan of the genus *Acanthogorgia* generates very dense patches, accompanied by other coral and sponge species such as *Viminella flagellum*, *Callogorgia verticillata* and *Paracalyptrophora josephinae*. In fact, this last primnoid can become very common, with colonies reaching very large sizes. Colonies of the yellow octocoral *Dentomuricea* aff. *meteor* also form patches of high densities. Several sponge aggregations have also been observed on the slopes, with an extensive species composition (e.g. cf. *Characella pachastrelloides*, *Macandrewia azorica*, cf. *Neophrissospongia nolitangere*, *Asconema* sp.). Colonies of the hydrocoral *Errina dabneyi* have been observed associated to a large number of species. The scleractinian coral *Eguchipsammia* has also been observed generating one extensive reef in at least one of the mounds.

Images of benthic communities

Image credits: © IMAR/OKEANOS-UAz, Drift camera



If a VME

Presence of endemic species *Dentomuricea* aff. *meteor* and CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*, and stylasterid *Errina dabneyi*. High diversity of species and communities. Dense coral gardens dominated by octocorals and sponges. Species with low growth and reproductive output vulnerable to fishing. Reefs of *Eguchipsammia cornucopia*, a species not known to form reefs elsewhere in the Atlantic and representing a potential relict species from geological past.

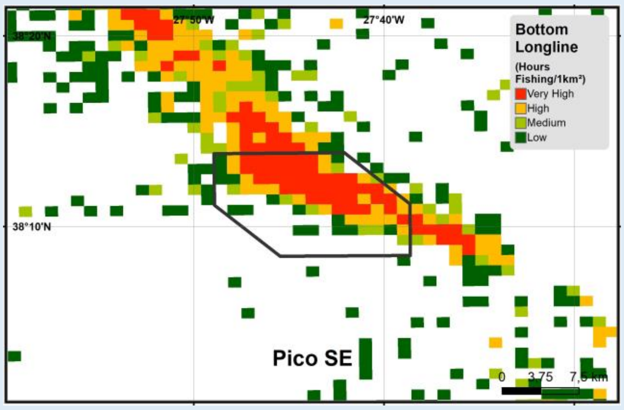
Existing regulations

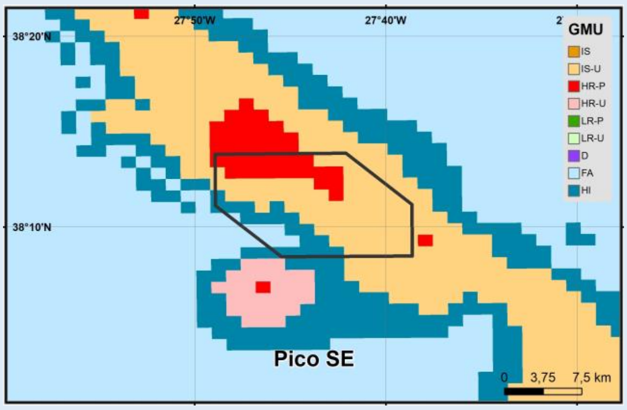
The Pico SE seamount area has no specific management regulation. However, it lies within the area for protection of deep-water corals from the effects of fishing; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation No. 1568/2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This area lies within 100 nautical miles from the island shores and fishing is restricted to vessels registered in Portugal (EC 1380/2013; in place until December 2022).

Human activities

The Pico SE seamount area is an important fishing ground for the local bottom longline/handline and pelagic longline fleet. It is also frequently visited by the mainland Portugal pelagic longline fleet and occasionally visited by the local pole-and-line fleet targeting tuna species.

Fishing intensity — Seabed Habitats





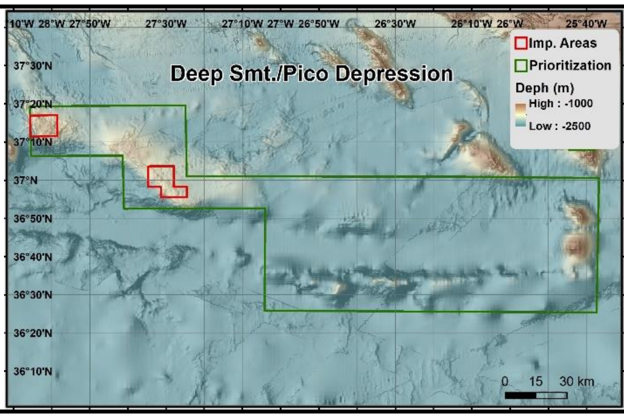
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	6 dives with the drift-cam system between 320-480 m depth

Deep seamounts / Pico depression

Cost model	AB + FB
Type	Seamount & Depression
Code	I21
Classification criteria	Important Area
Main features	Deep seamount

Area (km)	11,006
Depth range (m)	700-4044
Distance neighbour (km)	14
Bottom fishing effort (%)	0.1
Existing MPAs	-



Environmental setting

The “Deep seamounts / Pico depression” area is located across the East Azores fracture zone, which divides the Azores plateau (a.k.a. Azores microplate) from the Nubia (a.k.a African) tectonic plate. This area contains a very diverse geomorphological setting encompassing the East Azores FZ, Santa Maria Hills (deep seamounts), the Trident Ridge, and the Pico trough (names as described in GEBCO). This huge area lies about 65 nm south of Pico and spreads until 20 nm from Santa Maria island. This area is likely under the influence of the North Atlantic Central Water, the Mediterranean Outflow Water and the North Atlantic Deep Water below 2000 m depth.

Biological benthic communities

There is currently no information available regarding the composition and structure of the benthic communities present in this area.

Images of benthic communities

Image credits: © IMAR/OKEANOS-UAz, Drift camera

There are currently no images available regarding the benthic habitats of this area.

If a VME

The biology, ecology, and function of deep seamounts located in abyssal plains is poorly understood. However, recent studies have shown abyssal seamounts are hidden sources of increased habitat heterogeneity, with distinct benthic megafaunal diversity, and may act as valuable biodiversity reservoirs in the large abyssal plain.

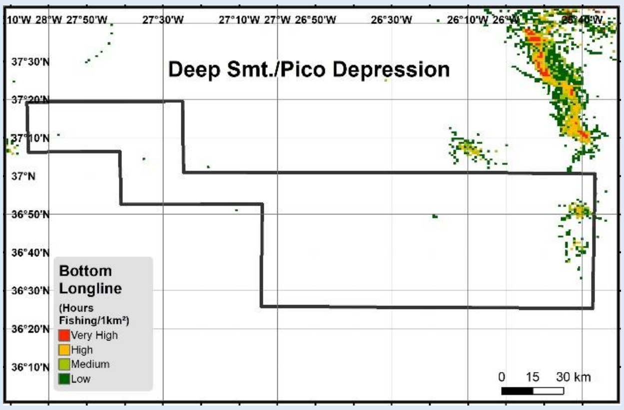
Existing regulations

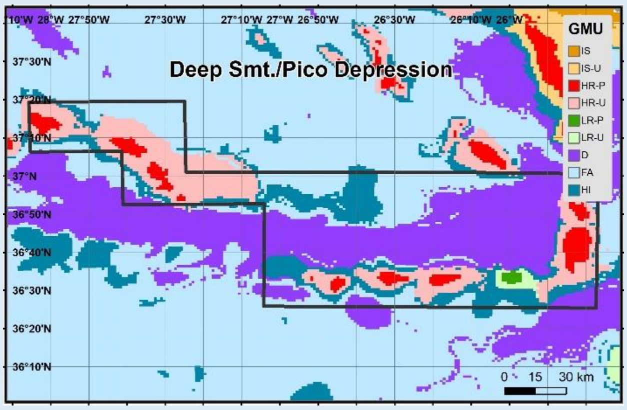
The "Deep seamounts / Pico depression" area lies within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This area also lies within 100 nautical miles from the baselines of the Union outermost regions and therefore is not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

Human activities

The "Deep seamounts / Pico depression" area is not an important fishing ground for the local bottom longline fleet and might be only used on its eastern end, in an area probably known as Picoto. This fleet usually targets blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This area is only occasionally used by the local and mainland Portugal pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*). However, this might be an important area of operation for local pole-and-line fleet targeting tuna species.

Fishing intensity | Seabed Habitats

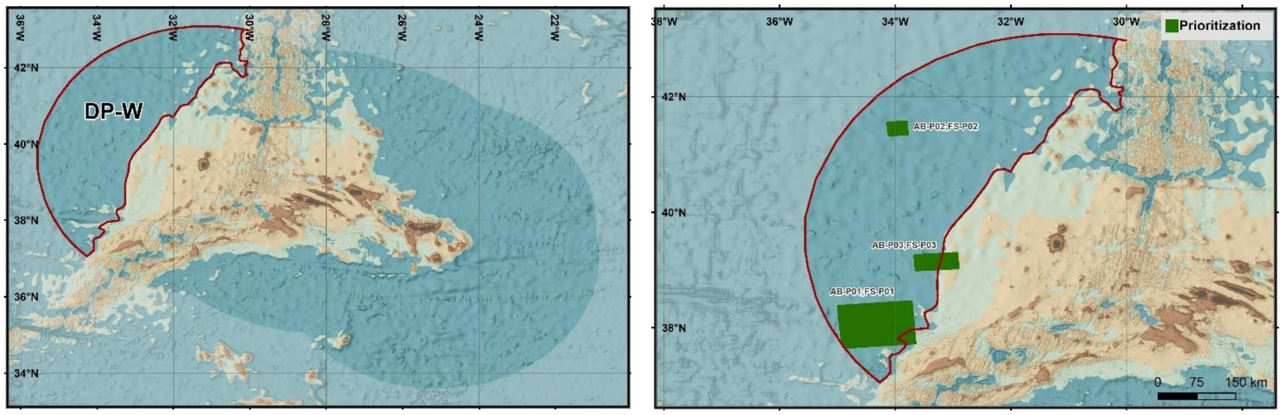




Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Prioritization areas | "Data-poor" West



P01 Pico Fracture Zone (AB + FS)

Pico Fracture Zone was included as prioritization area of the "data-poor" West because it includes a wide variety of seabed habitats, ranging from flat abyssal plains and low relief areas to hills and high-relief peaks, most likely providing several ecological niches to a large number of benthic species and communities.

Area (km)	9,112
Depth range (m)	1838-4266
Distance neighbour (km)	60
Bottom fishing effort (%)	-
Existing MPAs	-

P02 Flores Oceânico (AB + FS)

Flores Oceânico was included as prioritization area of the "data-poor" West because it represents a large depression area in the middle of the flat abyssal plain.

Area (km)	693
Depth range (m)	3791-4345
Distance neighbour (km)	76
Bottom fishing effort (%)	-
Existing MPAs	-

P03 Sarda North (AB + FS)

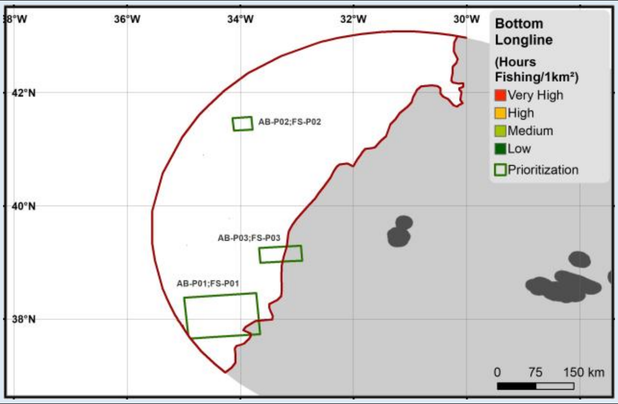
Sarda North was included as prioritization area of the "data-poor" West because it represents a large depression area in the middle of the flat abyssal plain.

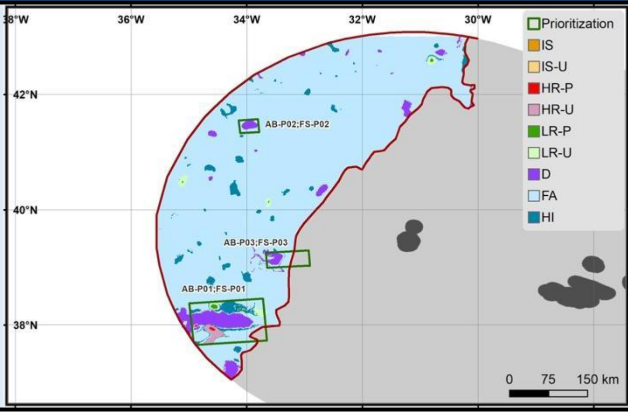
Area (km)	1,876
Depth range (m)	1546-3384
Distance neighbour (km)	60
Bottom fishing effort (%)	-
Existing MPAs	-

Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Fishing intensity	Seabed Habitats





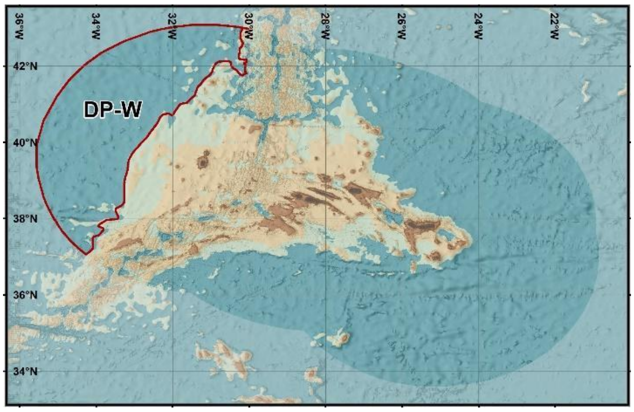
Existing regulations

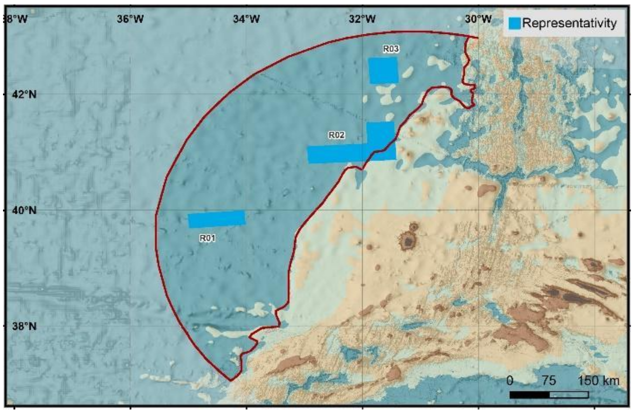
These areas are too deep for the bottom fishing industry. Nevertheless, Sarda North and a small portion of Pico Fracture Zone lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. Sarda North is also partially within the 100 nautical miles from the baselines of the Union outermost regions and therefore are not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

Human activities

These areas areas are too deep for the bottom fishing industry and therefore are not used by the local bottom longline fleet. However, Pico Fracture Zone is regularly visited by the EU pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*), while mainland Portugal fleet overlaps with the area named Sarda North. The area Flores Oceânico is only occasionally visited by the PT and EU pelagic longline fleets. The local pole-and-line fleet targeting tuna species does not overlap with these areas.

Representativity areas | “Data-poor” West





R01 Azores West (AB + FS)

Azores West was included as a representativity area of the “data-poor” West to increase the amount of flat abyssal plains included in the solutions, favoring the connectivity between these areas along the latitudinal gradient.

Area (km)	2,144
Depth range (m)	3271-4325
Distance neighbour (km)	54
Bottom fishing effort (%)	-
Existing MPAs	-

R02 Corvo Oceânico (AB + FS)

Corvo Oceânico was included as a representativity area of the “data-poor” West to increase the amount of flat abyssal plains included in the solutions, favoring the connectivity between these areas along the latitudinal gradient.

Area (km)	5,588
Depth range (m)	2113-3495
Distance neighbour (km)	31
Bottom fishing effort (%)	-
Existing MPAs	PMA 06

R03 North of HRC (AB + FS)

North of HRC was included as a representativity area of the “data-poor” West to increase the amount of flat abyssal plains included in the solutions, favoring the connectivity between these areas along the latitudinal gradient.

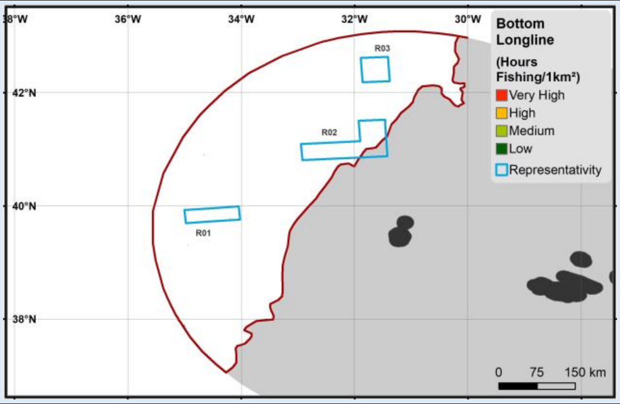
Area (km)	1,887
Depth range (m)	2612-3309
Distance neighbour (km)	73
Bottom fishing effort (%)	-
Existing MPAs	-

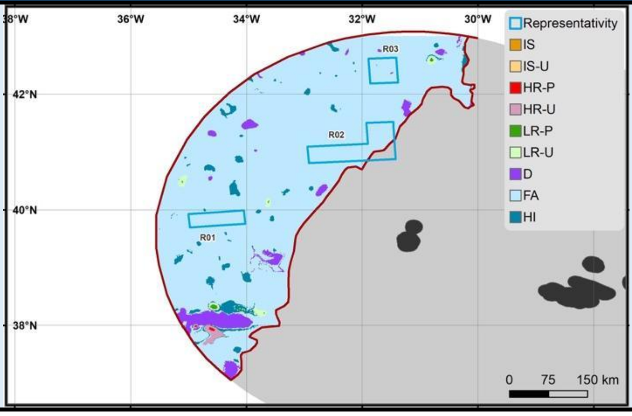
Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Fishing intensity

Seabed Habitats





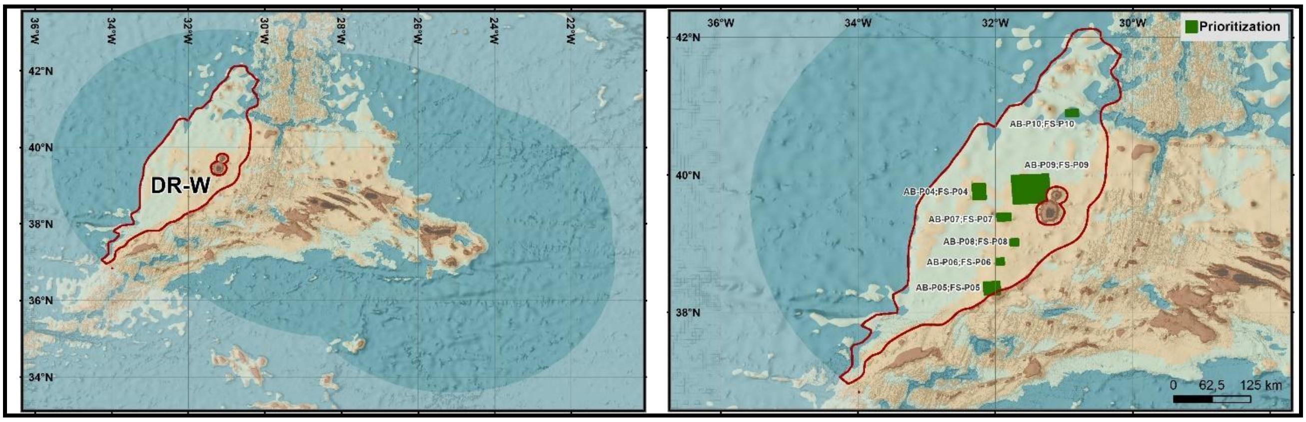
Existing regulations

Corvo Oceânico area is contained in the Azores Marine Park (PMA 06) as an important seabird area but lack effective protection measures (DLR 13/2016/A). These areas are too deep for the bottom fishing industry. Nevertheless, Corvo Oceânico lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. Corvo Oceânico also partially lies within the 100 nautical miles from the baselines of the Union outermost regions and therefore are not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

Human activities

These areas areas are too deep for the bottom fishing industry and therefore are not used by the local bottom longline fleet. However, these three areas are regularly visited by the mainland Portugal pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*), while EU fleet overlaps with the area named Azores West. The local pole-and-line fleet targeting tuna species does not overlap with these areas.

Prioritization areas | “Data-rich” West



P04 West of Corvo (AB≠FS)

West of Corvo was included as prioritization area of the “data-rich” West because it is characterized by flat abyssal plains that help towards achieving a good representation of the different benthic habitats that can be found in this area.

	AB	FS
Area (km)	384	150
Depth range (m)	1737-2025	1775-2018
Distance neighbour (km)	28	28
Bottom fishing effort (%)	-	-
Existing MPAs	-	-

P05 Buchanan (AB≠FS)

Buchanan was included as prioritization area of the “data-rich” West because it contains areas characterized by habitats of “Hills and lower slopes” and “High relieves”, which could indicate the presence of hard substrates colonized by diverse benthic communities.

	AB	FS
Area (km)	399	248
Depth range (m)	869-1488	1141-1478
Distance neighbour (km)	28	28
Bottom fishing effort (%)	0.04	0.00
Existing MPAs	-	-

P06 Bugio South (AB+FS)

Bugio South was included as prioritization area of the “data-rich” West because it is characterized by flat abyssal plains that help towards achieving a good representation of the different benthic habitats that can be found in this area.

Area (km)	99
Depth range (m)	947-1294
Distance neighbour (km)	22
Bottom fishing effort (%)	0.01
Existing MPAs	-

P07 Cachalote (AB+FS)

Cachalote was included as prioritization area of the “data-rich” West because it represents one of the few seamounts found in this area. Its high relieves could be favoring the development of rich benthic communities in an area surrounded by flat abyssal plains.

Area (km)	199
Depth range (m)	461-1901
Distance neighbour (km)	16
Bottom fishing effort (%)	3.96
Existing MPAs	-

P08 Bugio North (AB+FS)

Bugio North was included as prioritization area of the “data-rich” West because it includes seabed habitats considered of “Low relief” in the middle of the flat abyssal plain, which are very rare in this area.

Area (km)	99
Depth range (m)	749-1265
Distance neighbour (km)	22
Bottom fishing effort (%)	0.00
Existing MPAs	-

P09 Flores and Corvo (AB≠FS)

Flores and Corvo area was included as prioritization area of the "data-rich" West because it is characterized by flat abyssal plains that help towards achieving a good representation of the different benthic habitats that can be found in this area.

	AB	FS
Area (km)	1977	1399
Depth range (m)	980-2078	1083-2026
Distance neighbour (km)	16	16
Bottom fishing effort (%)	-	-
Existing MPAs	-	-

P10 Kurchatov West (AB+FS)

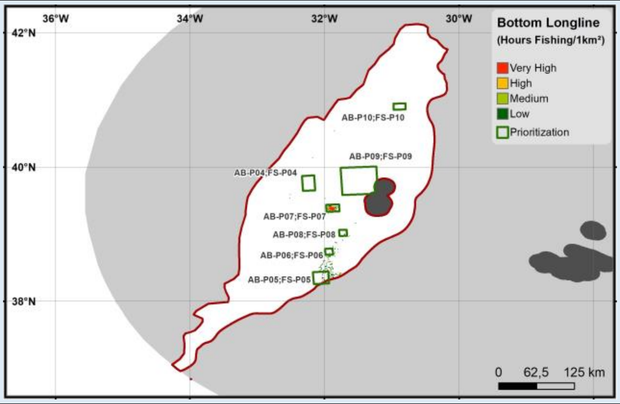
Kurchatov West was included as prioritization area of the "data-rich" West because it includes seabed habitats considered "Depressions" that are found in the middle of the flat abyssal plain, a type of habitat that can be considered rare in this area.

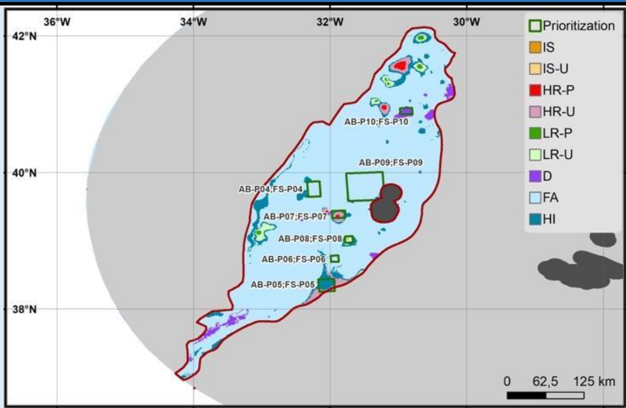
Area (km)	150
Depth range (m)	2416-3016
Distance neighbour (km)	38
Bottom fishing effort (%)	-
Existing MPAs	-

Scientific knowledge

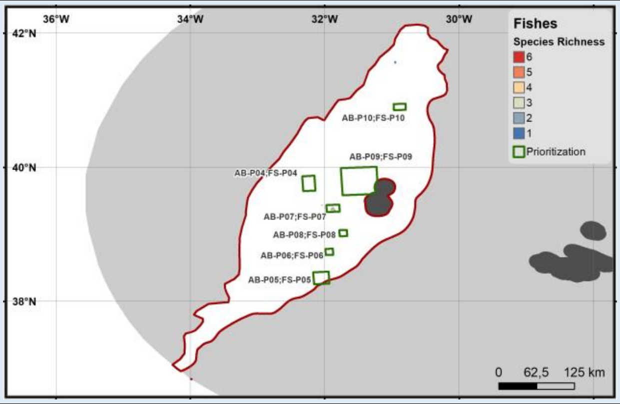
Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

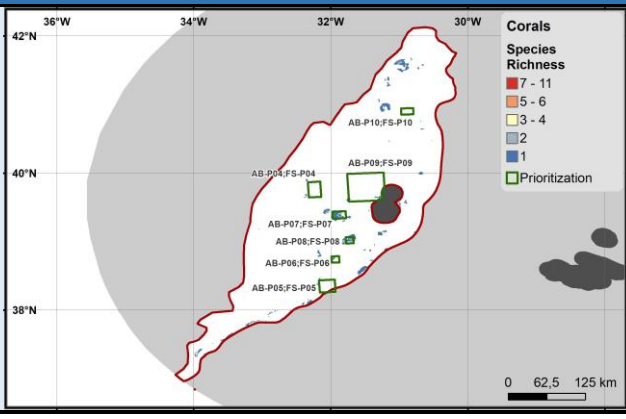
Fishing intensity | Seabed Habitats





Fishing intensity | Seabed Habitats

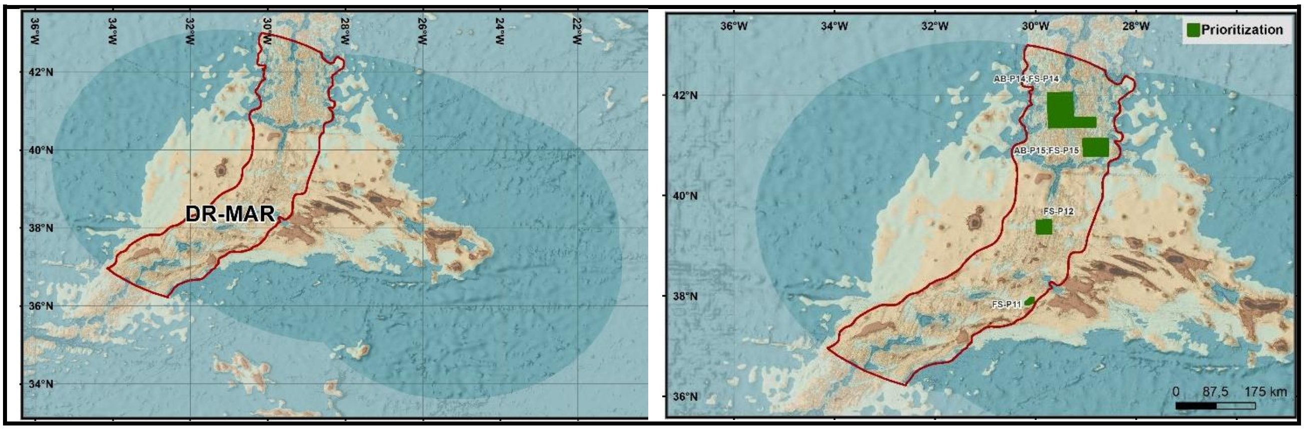




Existing regulations
These areas lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. All these areas lie within 100 nautical miles from the baselines of the Union outermost regions and therefore are not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

Human activities
Cachalote seamount is an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. All these areas have very limited use (if any) by the local and mainland Portugal pelagic longlining fleet or the local pole-and-line fleet targeting tuna species.

Prioritization areas | "Data-rich" MAR



P11 Alberto do Monaco North (FS)

Alberto do Monaco North was included as prioritization area of the "data-rich" MAR because it includes depressions and hills and promote connectivity with the adjacent Azores plateau.

Area (km)	150
Depth range (m)	1532-2032
Distance neighbour (km)	38
Bottom fishing effort (%)	-
Existing MPAs	-

P12 Gigante North (FS)

Gigante North was included as prioritization area of the "data-rich" MAR because it includes areas of depression, hills and lower slopes, which complements the seabed habitats that make up most of the important areas selected for the MAR.

Area (km)	750
Depth range (m)	719-2581
Distance neighbour (km)	20
Bottom fishing effort (%)	-
Existing MPAs	-

P14 Faial Oceânico (AB + FS)

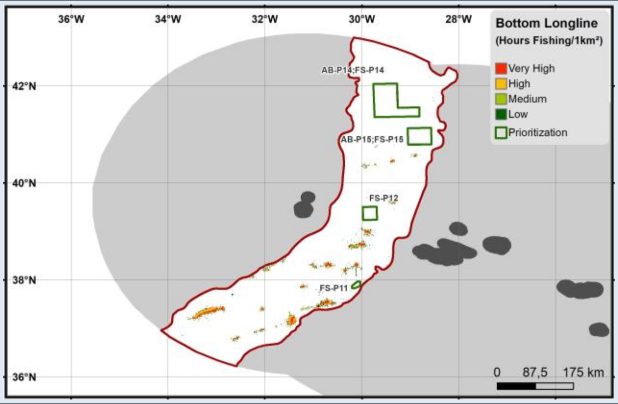
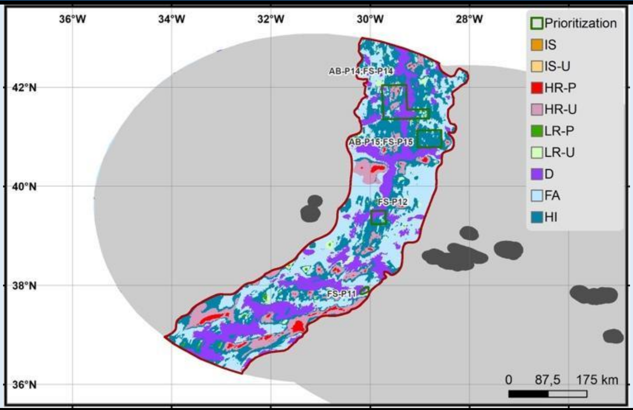
Faial Oceânico was included as prioritization area of the "data-rich" MAR because it includes several seabed habitats, from depressions to hills and high relief peaks, possibly encompassing a high number of benthic communities associated to the MAR.

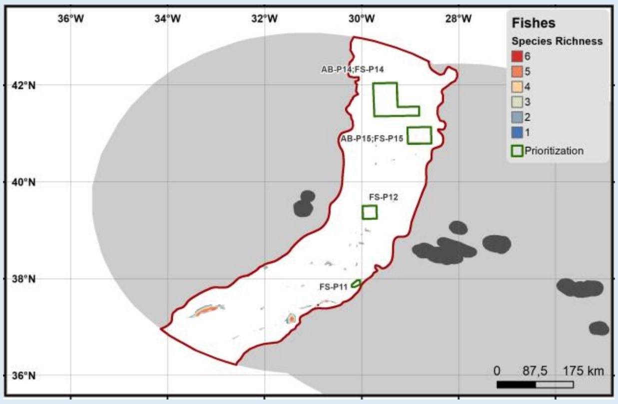
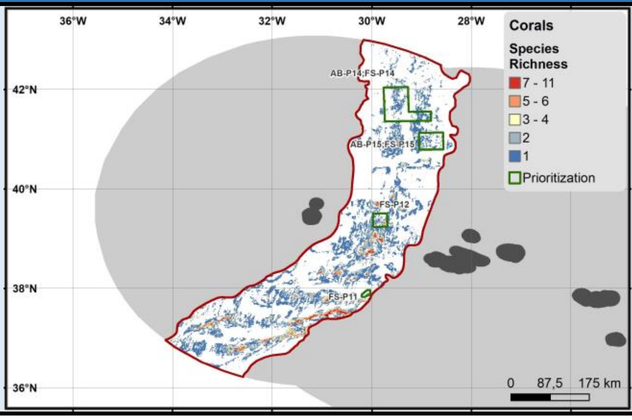
Area (km)	3817
Depth range (m)	830-3215
Distance neighbour (km)	27
Bottom fishing effort (%)	-
Existing MPAs	PMA 07

P15 Kurchatov NE (AB + FS)

Kurchatov NE was included as prioritization area of the "data-rich" MAR because it is mainly composed of seabed habitat defined as "Hills and lower slopes", an environmental setting not very represented along the southern part of the MAR.

Area (km)	1542
Depth range (m)	1439-2389
Distance neighbour (km)	27
Bottom fishing effort (%)	-
Existing MPAs	-

Fishing intensity	Seabed Habitats
	

Summary deep-sea fishes	Summary cold-water corals
	

Existing regulations

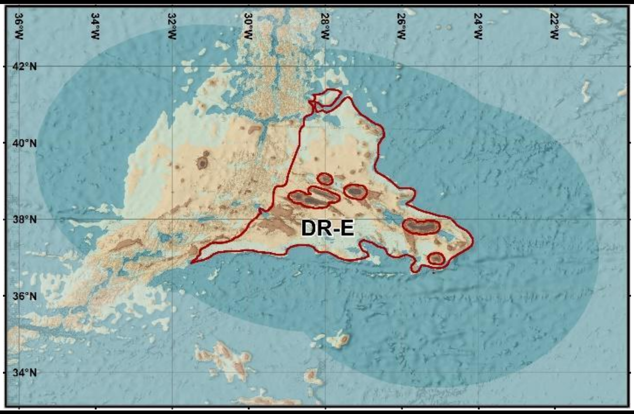
Faial Oceânico area is contained in the Azores Marine Park (PMA 07) as an important seabird area but lack effective protection measures (DLR 13/2016/A). These areas lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. The areas named Alberto do Monaco North and Gigante North lie within 100 nautical miles from the baselines of the Union outermost regions and therefore are not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

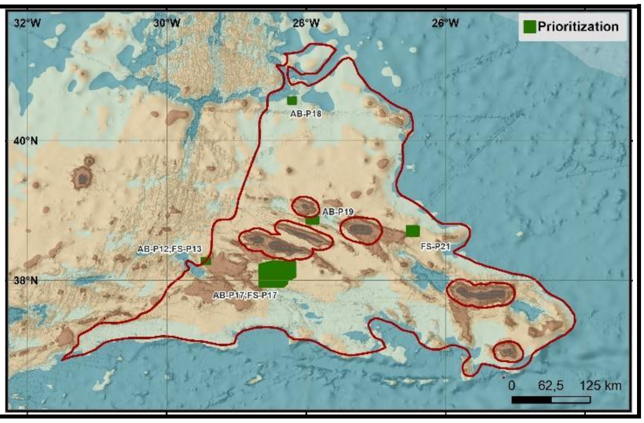
Human activities

These areas are too deep for the bottom fishing industry and therefore are not used by the local bottom longline fleet. However, all these areas are regularly visited by the mainland Portugal pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*), while EU fleet overlaps with the area named Faial Oceânico and Kurchatov. The local pelagic longlining or the pole-and-line fleet targeting tuna species do not overlap with these areas.

Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	





P12 Condor de Fora West (AB + FS)

Condor de Fora West was included as prioritization area of the “data-rich” East because it contains low relief areas, not very common in this region of the Azores and complements the selection made with the important areas, which cover other types of seabed habitats.

Area (km)	100
Depth range (m)	485-1314
Distance neighbour (km)	8
Bottom fishing effort (%)	0.7
Existing MPAs	-

P17 S. Mateus South (AB ≠ FS)

S. Mateus South was included as prioritization area of the “data-rich” East because in a small area it includes a wide variety of seabed habitats, from flat abyssal plains and depressions to low relief and hills, likely providing several ecological niches to a large number of benthic species and communities.

	AB	FS
Area (km)	1,575	900
Depth range (m)	424-2243	594-2243
Distance neighbour (km)	25	29
Bottom fishing effort (%)	0.3	0.03
Existing MPAs		-

P18 East of Kurchatov (AB)

East of Kurchatov was included as prioritization area of the “data-rich” East because it contains low relief areas, not very common in this region of the Azores and complements the selection made with the important areas, which cover other types of seabed habitats.

Area (km)	99
Depth range (m)	1421-2411
Distance neighbour (km)	32
Bottom fishing effort (%)	-
Existing MPAs	-

P19 Ilha Azul (AB)

Ilha Azul was included as prioritization area of the “data-rich” East because it contains low relief areas, not very common in this region of the Azores and complements the selection made with the important areas, which cover other types of seabed habitats.

Area (km)	149
Depth range (m)	395-2119
Distance neighbour (km)	62
Bottom fishing effort (%)	1,4
Existing MPAs	-

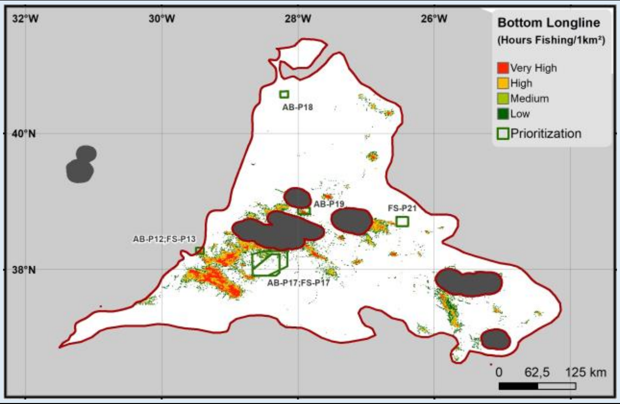
P21 Maçarico East (FS)

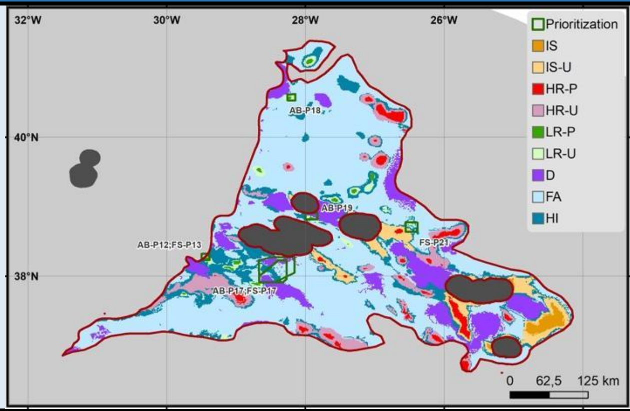
Maçarico East was included as prioritization area of the “data-rich” East because it contains low relief areas, not very common in this region of the Azores and complements the selection made with the important areas, which cover other types of seabed habitats.

Area (km)	225
Depth range (m)	546-2043
Distance neighbour (km)	37
Bottom fishing effort (%)	0.01
Existing MPAs	-

Fishing intensity

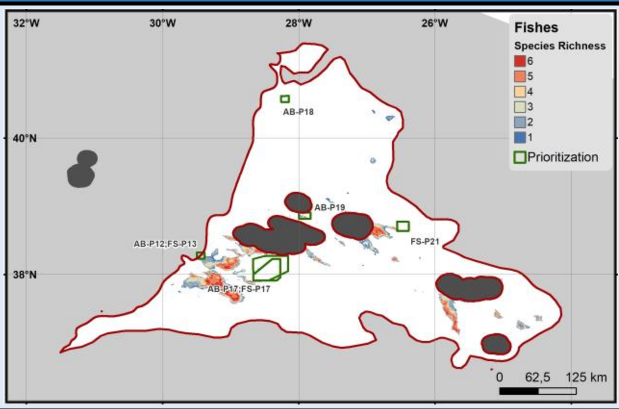
Seabed Habitats

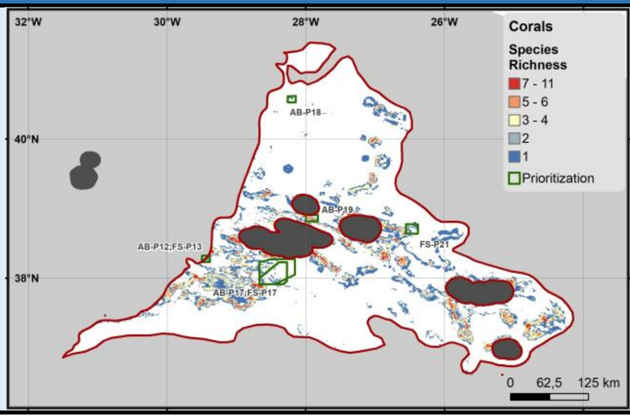




Summary deep-sea fishes

Summary cold-water corals





Existing regulations

These areas lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. These areas also lie within 100 nautical miles from the baselines of the Union outermost regions and therefore are not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

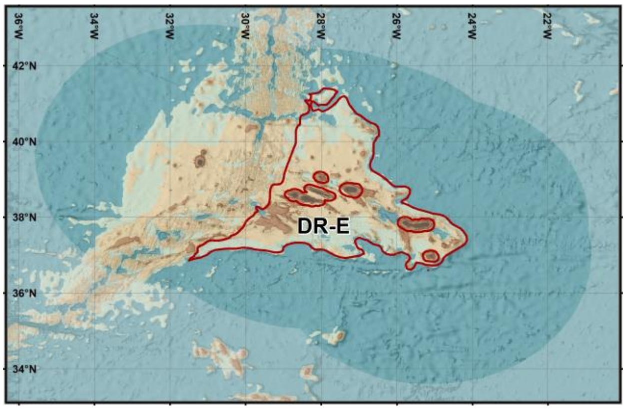
Human activities

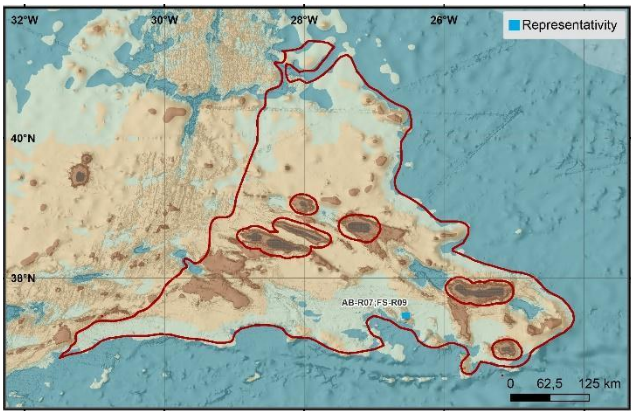
Ilha Azul seamount is an important fishing ground for the local bottom longline fleet targeting blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) and other deep-water demersal fishes. This fleet also uses the areas named Condor de Fora West and S. Mateus South. These two seamount are also visited by the local nad mainland Portugal pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*). All these areas area visited by the local pole-and-line fleet targeting tuna species.

Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Representativity areas | “Data-rich” East



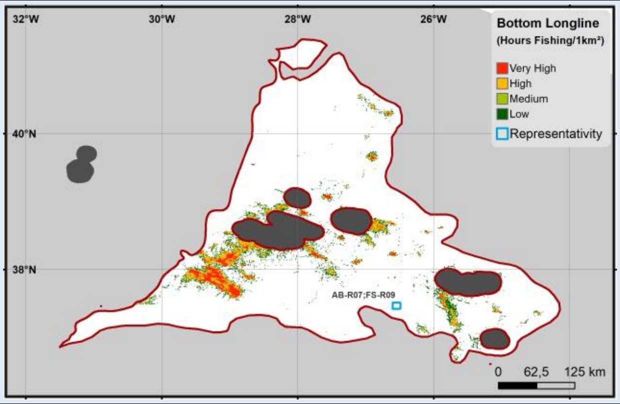


R07 Girard Ridge South (AB + FS)

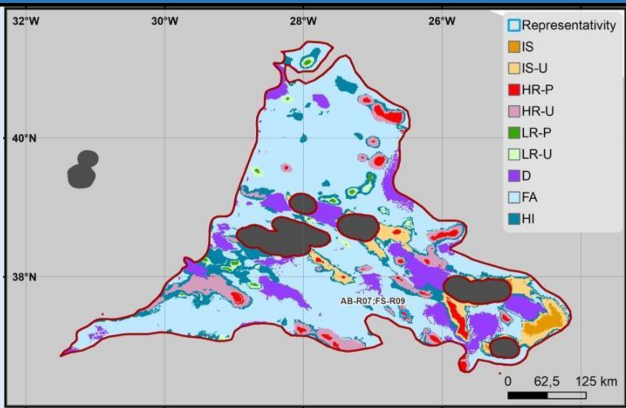
The Girard Ridge South was designated as a priority areas to increase the connectivity of the network of priorities areas in a specific area south of São Miguel that was considered isolated. This ridge is also important to increase the representativity of high relief seabed habitats in this region.

Area (km)	100
Depth range (m)	712-2381
Distance neighbour (km)	45
Bottom fishing effort (%)	-
Existing MPAs	-

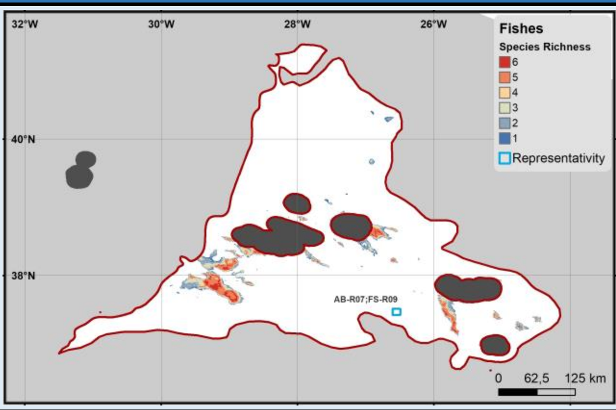
Fishing intensity



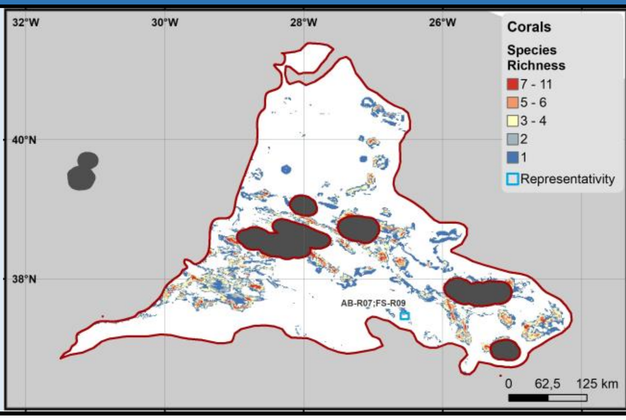
Seabed Habitats



Summary deep-sea fishes



Summary cold-water corals



Existing regulations

The Girard Ridge South area lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. This area also lies within 100 nautical miles from the baselines of the Union outermost regions and therefore are not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

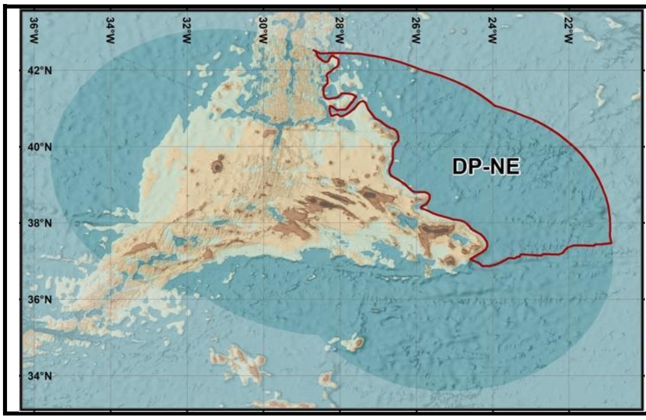
Human activities

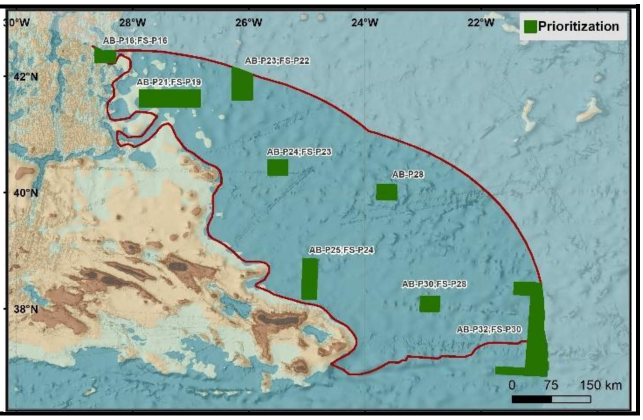
The Girard Ridge South area is only occasionally visited by the local and mainland Portugal pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*). This area is not visited by the local pole-and-line fleet targeting tuna species and is too deep for the local bottom longline fleet

Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Prioritization areas | “Data-poor North-east”





P16 Chaucer East (AB + FS)

Chaucer east was included as prioritization area of the “data-poor” North-east because it includes several seabed habitats (Hills, Depression, Low relief and Flat areas), and can be considered a transition area between the MAR and the flat abyssal plains.

Area (km)	618
Depth range (m)	1613-3081
Distance neighbour (km)	57
Bottom fishing effort (%)	-
Existing MPAs	-

AB-P21; FS-P19 Graciosa Oceânico (AB + FS)

Graciosa Oceânico was included as prioritization area of the “data-poor” North-east because it includes a High-relief peak, a feature not commonly found on the flat abyssal plain. The presence of deep seamounts is generally linked to increases in benthic diversity.

Area (km)	2670
Depth range (m)	1107-3224
Distance neighbour (km)	47
Bottom fishing effort (%)	0.00
Existing MPAs	-

AB-P23; FS-P22 Terceira Oceânico (AB + FS)

Terceira Oceânico was included as prioritization area of the “data-poor” North-east because it includes a High-relief peak, a feature not commonly found on the flat abyssal plain. The presence of deep seamounts is generally linked to increases in benthic diversity.

Area (km)	1540
Depth range (m)	1849-3550
Distance neighbour (km)	47
Bottom fishing effort (%)	-
Existing MPAs	-

AB-P24; FS-P21 Sedlo East (AB + FS)

Sedlo East was included as prioritization area of the “data-poor” North-east because it includes seabed habitats of “Hills and lower slopes”, likely to be hard substrate areas in the middle of the flat abyssal plain, which could be playing a major role in enhancing benthic diversity.

Area (km)	774
Depth range (m)	2598-3293
Distance neighbour (km)	40
Bottom fishing effort (%)	-
Existing MPAs	-

AB-P25; FS-P24 East of Heitor Alves (AB + FS)

East of Heitor Alves was included as prioritization area of the “data-poor” North-east because it includes a mixture of seabed habitats that range from depressions to hills, which could indicate a wide variety of ecological niches, and hence an elevated diversity of benthic communities.

Area (km)	1575
Depth range (m)	2296-3486
Distance neighbour (km)	34
Bottom fishing effort (%)	-
Existing MPAs	-

AB-P28 NE EEZ (AB + FS)

NE EEZ was included as prioritization area of the "data-poor" North-east because it includes seabed habitats considered of "Low relief" in the middle of the flat abyssal plain.

Area (km^2)	775
Depth range (m)	2996-3979
Distance neighbour (km)	121
Bottom fishing effort (%)	-
Existing MPAs	-

AB-P30; FS-P28 São Miguel East (AB + FS)

São Miguel East was included as prioritization area of the "data-poor" North-east because it includes a mixture of seabed habitats that range from depressions to hills, which could indicate a wide variety of ecological niches, and hence an elevated diversity of benthic communities.

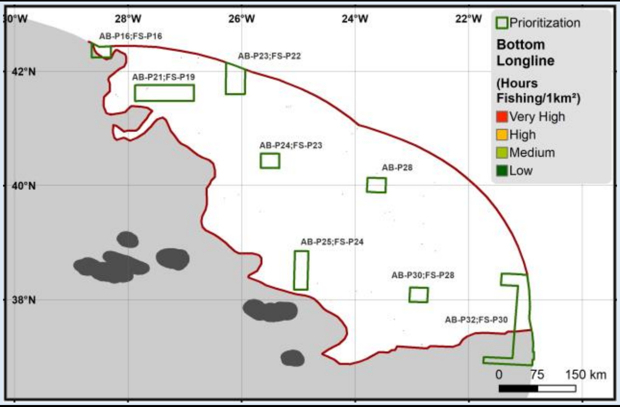
Area (km^2)	776
Depth range (m)	3246-4744
Distance neighbour (km)	50
Bottom fishing effort (%)	-
Existing MPAs	-

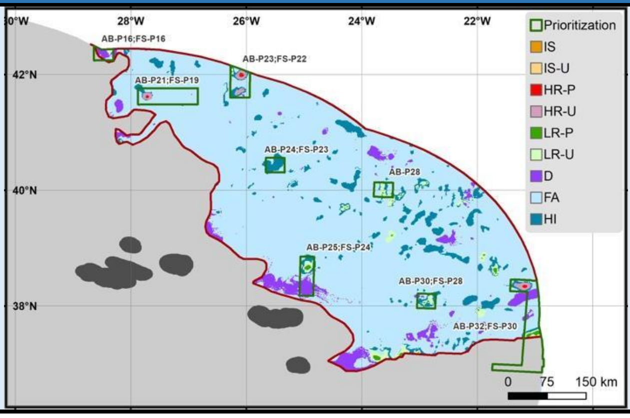
AB-P32; FS-P30 Azores East (AB + FS)

Azores East was included as prioritization area of the "data-poor" North-east because it includes a High-relief peak, a feature not commonly found on the flat abyssal plain. The presence of deep seamounts is generally linked to increases in benthic diversity.

Area (km^2)	5333
Depth range (m)	2978-5821
Distance neighbour (km)	112
Bottom fishing effort (%)	0.00
Existing MPAs	-

Fishing intensity | Seabed Habitats





Existing regulations

Most of these areas are too deep for the bottom fishing industry. Nevertheless, most of these areas, with the exception of NE EEZ and São Miguel East, lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. Most of these areas with the exception of East of Heitor Alves, lie beyond 100 nautical miles from the baselines of the Union outermost regions and therefore are accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

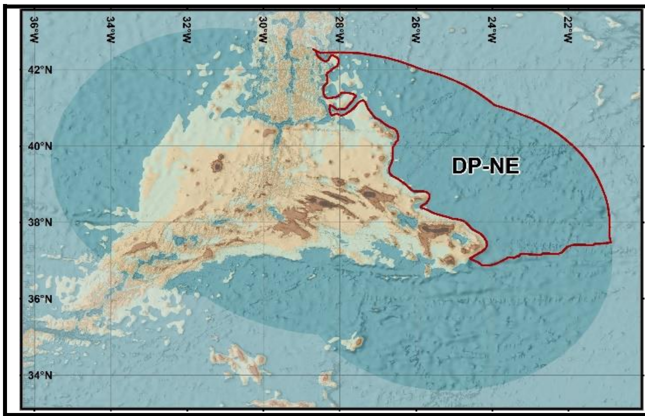
Human activities

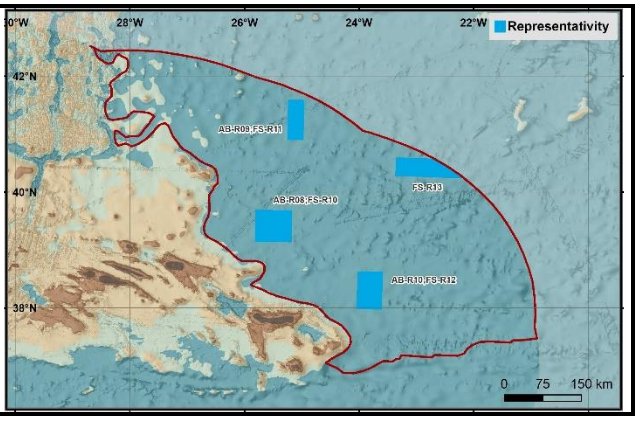
These areas areas are too deep for the bottom fishing industry and therefore are not used by the local bottom longline fleet. Sedlo East, NE EEZ, and São Miguel East are occasionally visited by the local and mainland Portugal pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*), while the EU fleet activity mostly overlaps with Sedlo East and Azores East. The local pole-and-line fleet targeting tuna species occasionally overlaps with the area Azores East.

Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Representativity areas | “Data-poor North-east”





AB-R08; FS-R10 East of Borba (AB+FS)

East of Borba was included as a representativity area of the “data-poor” northeast to increase the amount of flat abyssal plains included in the solutions, favouring the connectivity with the Azores plateau.

Area (km)	3201
Depth range (m)	2871-3446
Distance neighbour (km)	34
Bottom fishing effort (%)	0.00
Existing MPAs	-

AB-R09; FS-R11 São Miguel Oceânico (AB+FS)

São Miguel Oceânico was included as a representativity area of the “data-poor” northeast to increase the amount of flat abyssal plains included in the solutions and to increase the connectivity with the northeastern most region of the Azores EEZ.

Area (km)	1696
Depth range (m)	2822-3679
Distance neighbour (km)	40
Bottom fishing effort (%)	0.00
Existing MPAs	-

AB-R10; FS-R12 Abyssal São Miguel (AB+FS)

Abyssal São Miguel was included as a representativity area of the “data-poor” northeast to increase the amount of flat abyssal plains included in the solutions at this geographic locations. This area also increases the connectivity of the network.

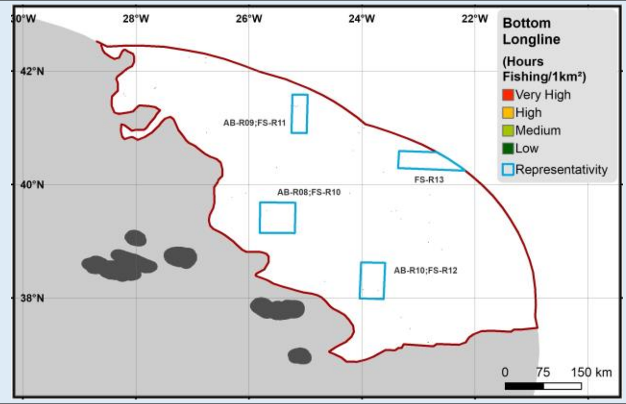
Area (km)	2639
Depth range (m)	3232-3835
Distance neighbour (km)	50
Bottom fishing effort (%)	0.00
Existing MPAs	-

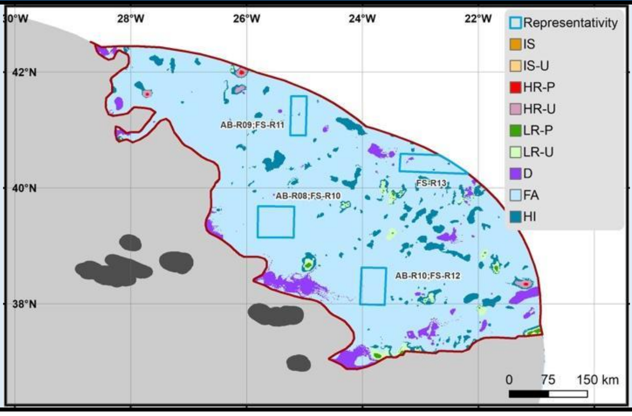
FS-R13 Azores NE (FS)

Azores NE was designated as a priority areas to increase the connectivity of the network of priorities areas in easternmost part of the Azores EEZ that was considered isolated. This area is also important to increase the representativity of flat abyssal plains in this region.

Area (km)	2692
Depth range (m)	3615-4466
Distance neighbour (km)	143
Bottom fishing effort (%)	-
Existing MPAs	-

Fishing intensity — Seabed Habitats





Existing regulations

Most of these areas are too deep for the bottom fishing industry. Nevertheless, most of these areas, with the exception of NE EEZ and São Miguel East, lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. The areas East of Borba and Abyssal São Miguel lie within the 100 nautical miles from the baselines of the Union outermost regions and therefore are not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

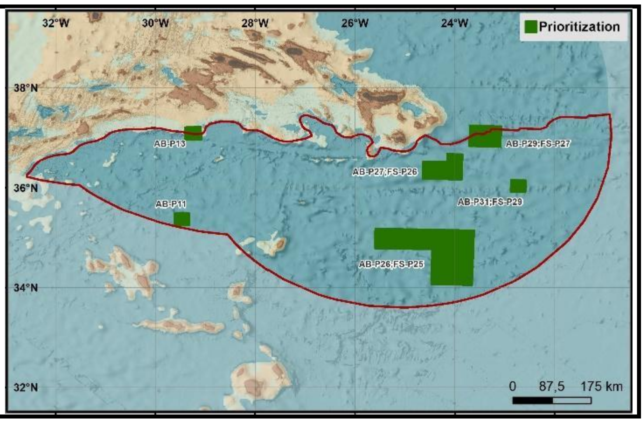
Human activities

These areas are too deep for the bottom fishing industry and therefore are not used by the local bottom longline fleet. The area São Miguel Oceânico is regularly visited by the local, mainland Portugal and EU pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*), while the area Azores NE also overlaps with the EU fleet activities. The local pole-and-line fleet targeting tuna species does not overlap with these areas.

Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Prioritization areas | "Data-poor" South-east



P11 East of Pico Sul (AB)

East of Pico Sul was included as prioritization area of the "data-poor" South-east because it includes seabed habitats of "Hills and lower slopes", likely to be hard substrate areas in the middle of the flat abyssal plain, which could be playing a major role in enhancing benthic diversity.

Area (km)	686
Depth range (m)	2650-3466
Distance neighbour (km)	43
Bottom fishing effort (%)	-
Existing MPAs	-

P13 Pettersson Escarpment (AB)

The Pettersson Escarpment was included as prioritization area of the "data-poor" South-east because it contains seabed habitats of "Hills and lower slopes" in an area characterized by low relieves and flat substrates, and hence locally enhancing benthic diversity.

Area (km)	774
Depth range (m)	1941-3486
Distance neighbour (km)	78
Bottom fishing effort (%)	-
Existing MPAs	-

AB-P26; FS-P25 Santa Maria Oceânico (AB + FS)

Santa Maria Oceânico was included as prioritization area of the "data-poor" South-east because it includes a wide variety of seabed habitats, ranging from flat abyssal plains and low relief areas to hills and high-relief peaks, most likely providing several ecological niches to a large number of benthic species and communities.

Area (km)	13,678
Depth range (m)	3424-5612
Distance neighbour (km)	110
Bottom fishing effort (%)	0.01
Existing MPAs	-

AB-P27; FS-P26 South of Gonçalo Velho (AB + FS)

South of Gonçalo Velho was included as prioritization area of the "data-poor" South-east because it contains seabed habitats of "Hills and lower slopes" while surrounded by flat areas, and likely playing a key role in enhancing benthic diversity locally.

Area (km)	3,132
Depth range (m)	2808-4463
Distance neighbour (km)	22
Bottom fishing effort (%)	0.003
Existing MPAs	-

AB-P29; FS-P27 Gloria Fracture Z. (AB + FS)

Gloria Fracture Z. was included as prioritization area of the "data-poor" South-east because it contains seabed habitats of "Hills and lower slopes" and "Low relief" while surrounded by flat areas, likely playing a key role in enhancing benthic diversity at the local scale.

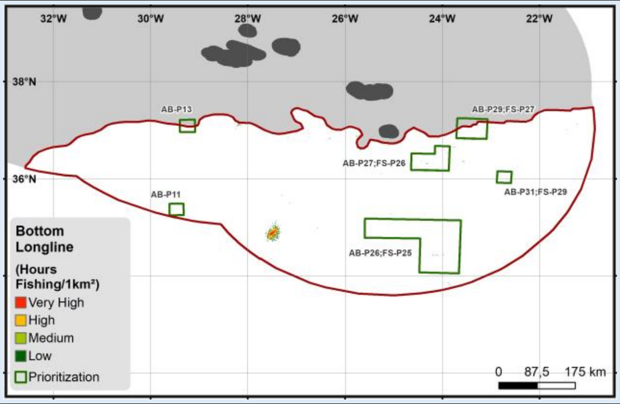
Area (km)	2,517
Depth range (m)	2731-5037
Distance neighbour (km)	22
Bottom fishing effort (%)	0.001
Existing MPAs	-

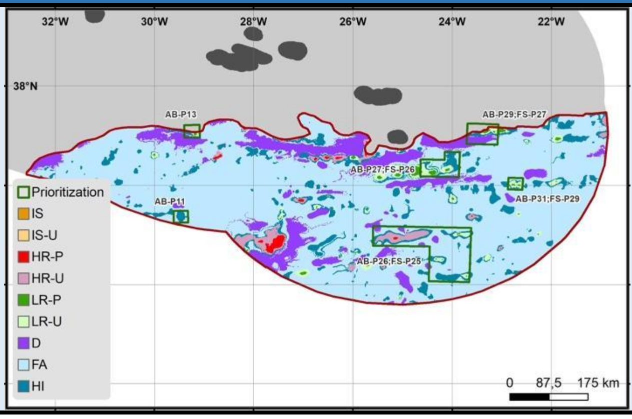
AB-P31; FS-P29 Azores East Fracture Zone (AB+FS)

Azores East Fracture Z. was included as prioritization area of the "data-poor" South-east because it contains seabed habitats of "Hills and lower slopes" and "Low relief" while surrounded by flat areas, likely playing a key role in enhancing benthic diversity at the local scale.

Area (km)	687
Depth range (m)	3570-4732
Distance neighbour (km)	58
Bottom fishing effort (%)	-
Existing MPAs	-

Fishing intensity — Seabed Habitats





Existing regulations

Most of these areas are too deep for the bottom fishing industry. Nevertheless, the areas Pettersson Escarpment, South of Gonçalo Velho and Gloria Fracture Zone, lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. These three areas also lie within the 100 nautical miles from the baselines of the Union outermost regions and therefore are not accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

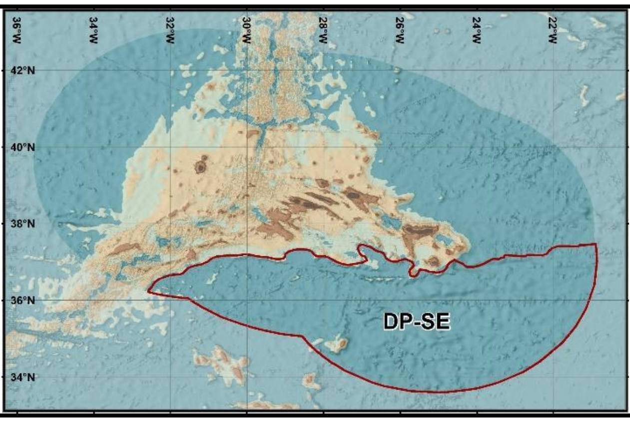
Human activities

These areas are too deep for the bottom fishing industry and therefore are not used by the local bottom longline fleet. However, the areas named South of Gonçalo Velho, Gloria Fracture Zone, and Azores East Fracture Zone are regularly visited by the mainland Portugal pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*); while the EU fleet mostly overlaps with the areas East of Pico Sul, Santa Maria Oceânico, and Azores East Fracture Zone. The local pelagic longlining fleets or the pole-and-line fleet activities do not overlap with these areas.

Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

Representativity areas | "Data-poor" South-east



R04 Monte Alto South (AB + FS)

Monte Alto South was included as a representativity area of the "data-poor" northeast to increase the amount of flat abyssal plains included in the solutions and to increase the connectivity with the MAR.

Area (km)	686
Depth range (m)	2289-2993
Distance neighbour (km)	27
Bottom fishing effort (%)	-
Existing MPAs	-

R05 North of Atlantis (AB ≠ FS)

North of Atlantis was also included as a representativity area of the "data-poor" northeast to increase the amount of flat abyssal plains included in the solutions and to increase the connectivity within the network, namely with Pico Sul / Meteor North.

	AB	FS
Area (km)	686	
Depth range (m)	2829-3621	
Distance neighbour (km)	55	93
Bottom fishing effort (%)	-	
Existing MPAs	-	

FS-R06 Abyssal Princesa Alice (FS)

Abyssal Princesa Alice was included as a representativity area of the "data-poor" northeast to increase the connectivity in the fisheries-based cost scenarios and to increase the representativity of high relief features in the solutions for this region.

Area (km)	770
Depth range (m)	2139-3514
Distance neighbour (km)	60
Bottom fishing effort (%)	-
Existing MPAs	-

AB-R06; FS-R07 Pico Sul / Meteor North (AB ≠ FS)

Pico Sul / Meteor North was included in the network for various reasons: 1) selected in the prioritization approach for being the only intermediate seamount in this region, 2) for being part of the Great Meteor MPA, and 3) as a representativity area to increase the amount of flat abyssal plains included in the solutions.

	AB	FS
Area (km)	17,289	
Depth range (m)	336-4439	
Distance neighbour (km)	43	24
Bottom fishing effort (%)	1.7	
Existing MPAs	PMA 12	

FS-R08 Abyssal Pico Sul (FS)

Abyssal Pico Sul was included as a representativity area of the "data-poor" northeast to increase the connectivity in the fisheries-based cost scenarios and to increase the representativity of high relief features in the solutions for this region.

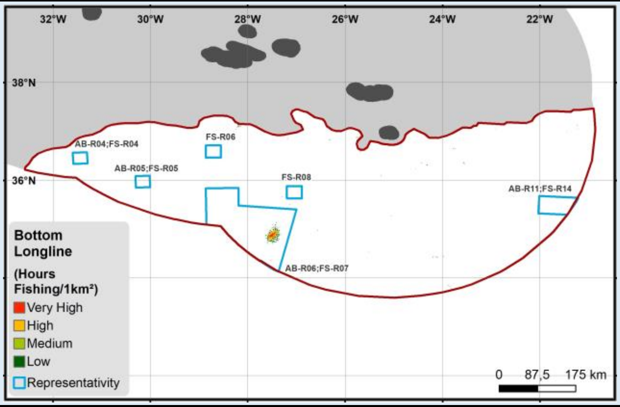
Area (km)	770
Depth range (m)	1555-4023
Distance neighbour (km)	24
Bottom fishing effort (%)	-
Existing MPAs	-

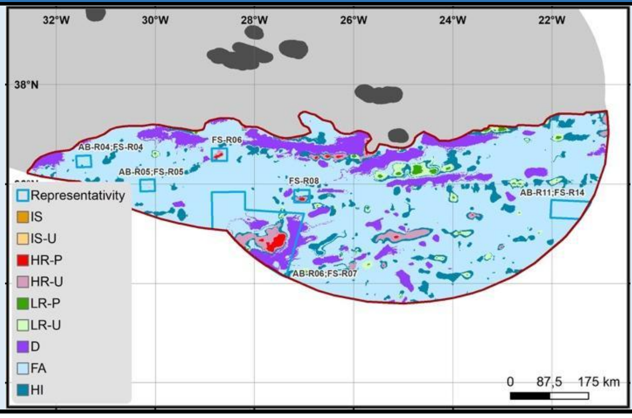
AB-R11, FS-R14 Azores SE (AB + FS)

Azores SE was included as a representativity area of the “data-poor” northeast to increase the amount of flat abyssal plains included in the solutions and to increase the connectivity the southeastern most part of the spatial planning area.

Area (km)	2549
Depth range (m)	4710-5242
Distance neighbour (km)	58
Bottom fishing effort (%)	-
Existing MPAs	-

Fishing intensity / Seabed Habitats





Existing regulations

Pico Sul / Meteor North area is contained in the Azores Marine Park (PMA 12) but lack effective protection measures (DLR 13/2016/A). Most of these areas are too deep for the bottom fishing industry. Nevertheless, the areas Monte Alto South, Abyssal Princesa Alice, and a small portion of the North of Atlantis, lie within the area for protection of deep-water corals from the effects of fishing in certain areas of the Atlantic Ocean; where bottom trawl or similar towed nets operating in contact with the bottom are prohibited (European Council Regulation [EC] No. 1568/2005 of 20 September 2005). This regulation also prohibits using any gillnet, entangling net or trammel net at depths greater than 200 meters. All areas lie beyond the 100 nautical miles from the baselines of the Union outermost regions and therefore are accessible to the EU fishing vessels (EC 1380/2013; in place until December 2022).

Human activities

These areas are too deep for the bottom fishing industry and therefore are not used by the local bottom longline fleet. However, these areas (but mostly Pico Sul/Meteor North) are regularly visited by the EU pelagic longlining fleet targeting swordfish (*Xiphias gladius*) and pelagic sharks (e.g., *Prionace glauca*). The local and mainland Portugal pelagic longlining fleets or the pole-and-line fleet activities do not overlap with these areas.

Scientific knowledge

Multibeam	
Oceanographic surveys	
Fisheries surveys	
Benthic surveys	

11. Conclusions

The systematic conservation planning for the deep-water of the Azores, suggested the prioritization outputs are highly dependent on the goals and objectives adopted. It also highlighted that the prioritization outputs, but also the performance assessment and the forecasted ecosystem outcomes depend on the range of conservation features, representation targets, cost model, boundary penalties, and constraints adopted. In general terms, besides the important areas locked-in the solutions, the resulting network of priority areas is spread throughout the whole EEZ, with a better representativity in most scenarios with low and medium clumping. The area-based cost solution, generally, obtained higher representativity for the shallow water depths while the fisheries-based cost scenarios obtained slightly higher representativity for deep waters. Not surprisingly, area-based cost scenarios included more fish suitable habitat in the solutions than the fisheries-based cost solution. Fisheries-based cost scenarios, generally reduced the overlap with existing fishing footprint and existing fishing effort.

The Azores Ecospace model comes with several caveats and uncertainties (Section 5.8.4) but has been demonstrated useful to project the ecosystem and fisheries impacts of several spatial management scenarios. One of the first conclusions of the ecosystem and fisheries projections was that under a Business as Usual Scenario assuming *status quo* levels of fishing effort and environmental conditions similar to those observed in recent years, the biomass and consequently catch of the largest majority of exploited benthic fish species were predicted to decrease over the coming years. This projection is in agreement with the recent evidences and anecdotal perceptions that some fish stocks in the Azores are being exploited above sustainable limits (Morato et al., 2012; ICES, 2017; 2019; Santos et al., 2019b). This supports the necessity of additional management measures that could halt or invert the decreasing trend.

The overarching conclusion of the forecasted ecosystem outcomes is that networks of MPAs in the Azores can have strong positive effects in the biomass of top-predators, and lead to spatial trophic cascade effects through the food-web. However, significant reshapes in the structure and likely functioning of the ecosystem were restricted within the reserve. The overall limited projected performance of MPA networks in delivering fisheries gains reflects that positive net effects of marine reserves on fishery spillover are more likely to be detected when fishing stocks are highly depleted (Buxton et al., 2014, Le Quesne & Codling, 2009). In these cases, achieving both conservation and fisheries objectives through the implementation of a network of marine protected areas may be particularly challenging. This aspect raises two questions: are Azores fisheries stocks not highly depleted? Or is the modelling approach not capturing local baseline conditions? We argue that both points might be valid.

Our model projections suggested that the "reserve effect", although well noticeable, was smaller than what has been typical reported for shallow-water and coastal environments (Halpern, 2003; Cheng et al., 2019). The projected smaller increase when compared to other studies might be related to the fact that most deep-sea species will take longer to recover due to their life-history characteristics (Devine et al., 2006; Marschoff et al., 2012). Additionally, due to the complex topography of the Azores EEZ, the spillover effects to neighbouring cells might be limited in off-shore and deep-water grounds, as the adjacent areas might not be suitable habitats and therefore lead to weak spillover effects (Freeman et al., 2009). This may also contribute to the observed reduced reserve effect within the time-frame projected in this study. Consequently, the implementation of "no-take areas" in the deep-sea may require longer time-frames when compared to those in shallow-water environments, <as already observed in other areas (Sackett et al., 2014). Closed areas that safeguard connectivity to suitable habitats (e.g. seamounts, island slopes) might reduce the time-frames required for recovery of deep-sea environments and be more appropriated to sustain fisheries catches (Tupper, 2007).

Our model also projected that the implementation of "no-take areas" should be accompanied by other fisheries management measures. We noted that the implementation of a MPA strategy projected potential detrimental effects in some shallow-water and coastal commercially important fisheries stocks. This may result from the displacement of fishing effort to coastal and shallower fishing grounds, with potentially negative effects on some fish stocks. This aspect highlights the need for specific prioritization approaches for the coastal areas and coastal and shallow water biodiversity. Notwithstanding, following the MPA implementation with additional fisheries tools (i.e., effort reductions) might be crucial to avoid local depletion of stocks in response to the displacement of fishing activities to non-protected grounds. These results are in line with Hilborn et al. (2004), suggesting that no-take areas should be accompanied by other fisheries management tools (i.e., catch or effort limits) in order to avoiding negative effects in the stocks and achieve conservation and ecosystem-based management goals. However, it is noteworthy that rebuilding fish stocks should not be considered the only management goal to be achieved and that the MPA strategy have additional positive outcomes (e.g. protection of VMEs) not measured with this approach.

Although there has been large of number of scientific research in recent years that supported the exploration and discovery of new species and ecosystems in the Azores, there still exist some knowledge gaps hampering the proper development of systematic conservation planning approaches and the development of policies that promote the sustainable use of deep sea natural resources. At the ecological level, although information exists on the diversity of species and communities from several underwater features including seamounts, ridges and island slopes, this information is mostly restricted to the upper 1,000 m depth. Geographically, the sampling effort has been mainly placed around the central Mid-Atlantic Ridge and around the islands of the central and eastern groups. Thus, there is very limited information about the underwater features that belong to the western group, as well as those seamounts and ridges located on the MAR north of Oscar seamount (39º 35' N). Furthermore, our understanding about how oceanographic processes and water masses shape the diversity, composition and distribution of benthic ecosystems is also very limited, both at present and under predicted future ocean conditions. Another important knowledge gap resides in the lack of information on what underwater features should be regarded as little impacted or pristine, since most seamounts have some level of longline fishing. This situation limits our ability to describe the baseline conditions of these ecosystems in terms of ecosystem structure and species composition to be used as targets for conservation/restoration measures.

Classic studies show that a direct relationship exists between biodiversity and ecosystem functioning for deep-sea ecosystems (Snelgrove et al., 2014; Zeppilli et al., 2016), and thus better preserved and biodiverse ecosystems are assumed to play more functional roles. However, recent works suggest that functional attributes of communities may affect ecosystem processes and services more than species richness (Snelgrove et al., 2018). Thus, a better understanding of the functional diversity of ecosystems can help identify the guild of species that most influence ecosystem functions and how they respond to environmental change or disturbance (Diaz et al., 2013). In the Azores, a large number of taxa has been identified living in association with emblematic benthic ecosystems, such as coral gardens (Porteiro et al., 2013; Braga-Henriques et al., 2015). However, detailed information on associated species composition and ecological interactions is currently limited. For example, there is some information on symbiotic associations of corals and gastropods or zoantharia (e.g. Braga-Henriques et al., 2011; Carreiro-Silva et al., 2017), but no data exists on predator-prey relationships and identification of keystone species, which ultimately play an important role on ecosystem structure and functioning. This information is nearly absent for sponge aggregations. In addition, knowledge on the functioning and services provided by benthic ecosystems is also poor. While coral gardens are known to provide essential habitat for some fish species (Porteiro et al., 2013; Pham et al., 2015; Gomes-Pereira et al., 2017), there is no proved evidence if (and how) these habitats are used as spawning sites. Furthermore, scientific knowledge is particularly scarce in relation to the roles that benthic species play in biogeochemical cycling, such as in nutrient regeneration, and carbon remineralization and sequestration. This issue has started to be addressed during the ATLAS project, suggesting that coral gardens in Condor seamount have organic matter cycling several times above "reference" sandy areas (Wolff et al., 2019).

At the organism level, there is limited information on species reproductive cycles, growth rates, larvae biology and dispersal, and recruitment for most habitat-forming species of corals and sponges in the Azores. This is due to challenges related to the collection of this information in situ, and to maintaining deep-sea species under *ex situ* aquaria conditions. The limited information collected so far suggests that octocorals, the main components of coral gardens, have low fecundity and larvae, with potentially low dispersal capabilities (Rakka et al., 2017; Carreiro-Silva et al., 2019). These life strategies may limit the connectivity between populations in different underwater features across the Azores. More studies are needed to confirm this information and assess how larvae biology may be affected under climate change conditions, in order to include such knowledge in the design of MPAs networks to guarantee species persistence (Fox et al., 2016). Furthermore, the limited knowledge on the physiological limits and adaptive capacity of deep-sea species to forecasted changes in climate, also hampers our ability to identify sensitive species and habitats and refuge areas that may be integrated in MPAs networks.

In terms of fisheries-related studies in the Azores, in particular for the quantification and distribution of fishing effort based on the data derived on the Vessel Monitoring System (VMS), some gaps exist regarding the fishing effort of smaller vessels. VMS provides detailed information on vessel activity and the geographic distribution of the fishing effort of larger vessels. In places like in the Azores, where the artisanal fleet is dominant, this information can create bias in the resulting maps of fishing effort. In particular, differences between bottom longliners and handliners are difficult to determine based on VMS data, but such distinction would be very useful since great differences exist between both fishing activities. Heuristic methods have been used to infer fishing state based on VMS data, but even if those methods are fine-tuned and validated using observer data, errors in state allocation remain unavoidable.

In the case that VMS data could be linked with catch composition (species, number, weight, and eventually including unwanted/unreported/discarded parts of the catch), a better and more accurate knowledge on fishing pressures on different components of the ecosystem could be described. Such knowledge is provided with observer data, but currently only represents a very limited proportion of the fishing effort. Filling knowledge gaps on socio-economic dynamics for the Azorean fisheries would also allow to assess more precisely how suggested closures would influence today's economic activity. In particular, a better distinction in socio-economic data between bottom longliners and handliners would help to fully understand their relative importance and impact for a sustainable use of fisheries resources.

There are also important knowledge gaps related to fisheries management and bycatch-related issues. Despite recent efforts towards better stock assessments of the main commercial species under quota, no official stock assessments have yet been performed. These results in total allowable catch (TACs) being set based on the precautionary approach, either according to levels of catch or relative abundance index. Considering the importance of those species for Azorean fisheries and socio-economy of the region, formal stock assessments would help evaluating the appropriate catch limits for those species, which ultimately could be used in systematic conservation planning to fine-tune results and provide more adjusted protection for those species. There is also a need for further genetic studies, since a better knowledge of population genetics would help to accurately preserve population stocks and biodiversity, with some potential application for fisheries management. Finally, better understanding the basic ecology and having a more accurate quantification of bycatch levels on highly vulnerable/threatened species, taken as bycatch with deep-sea longline fisheries, would help to better assess and fine-tune conservation threats and the sustainability of the bycatch.

Regarding the use of ecosystem modelling for management strategy evaluation, there are still some important knowledge gaps in need of improvement. The overall accuracy of models' projections is strongly related to the quality of the data used in the parametrization them (e.g., Smith et al., 2015). For example, absolute biomass estimations and diet compositions are crucial inputs stating the quality of baseline projections under the Ecopath with Ecosim modelling framework (e.g., Bentley et al., 2019). The construction of the Azores ecosystem model highlighted the lack of biomass estimates for the large majority of functional groups (Morato et al., 2016). Analytical stock assessment estimates would certainly improve the accuracy and robustness of the Azores model.

Notwithstanding, recognized knowledge gaps were also related to feeding habits and habitat suitability of prey components of the food-web. This was, for instances, the case of Euphausiidds, Polychaetes and shrimp's species, for which diet compositions were defined based on empirical knowledge, diet studies from different areas or derived from other models. Data limitations on these parameters raise uncertainty in regards to the trophic level estimated for each functional group and the structural role of some functional groups (e.g., cephalopods and pelagic sharks). Additionally, the role of habitat-forming species (e.g., corals and sponges) as mediators of predator-prey interactions is unclear (e.g., Brandl et al., 2019). For this reason, the explicit consideration of VMEs on the Azores ecosystem model is still difficult to explore.

In regards to dynamic models, it is of paramount importance to use accurate baseline data to drive and validate model projections, both at temporal and spatial-temporal scales. Time-series of fishing effort used to drive the Azores model, do not fully reflect technological advances in fisheries and improved catchabilities registered in the last decade. Consequently, responses of food-web components to fishing pressures were certainly underestimated. As stated above, existing indices of relative abundance used to calibrate and validate the model are originated from hook and line fishing surveys and, therefore come with increase uncertainties (Engas 1994). Besides, the data was only available for commercial species, while reference data on low trophic level groups and top predators was missing but would be paramount to improve model predictions.

The spatial-temporal feature of the modelling approach requires information of the habitat preferences and dispersal rates of functional groups. Habitat suitability studies based in the Azores, and tagging data, is available for some commercial species and high trophic level species, as deep-sea sharks, whales and dolphins. However, little is known about habitat relationships of low trophic level groups, which raises uncertainty regarding habitat allocations defined in the model.

Another important pitfall, advancing large sources of uncertainty in model estimations, is transversal among deep-sea ecosystems and relies on what are the main drivers of ecosystem dynamics. Environmental variability seems to be the key driver of the Azores ecosystem, but the factors and mechanisms underpinning such dynamics are unknown. For that reason, the function shaping the contribution of regime shifts impacting the biomass of primary producers in the Azores Ecosim and Ecospace models is theoretical, as it derived from model predictions. Forecasting uses of the model, demand assumptions regarding future environmental conditions, which considerably enhances model uncertainty, namely under a changing planet (e.g., Niiranen et al., 2012). It is therefore acknowledged that Ecospace predictions regarding ecosystem impacts of MPAs, do have this major source of uncertainty associated.

This exciting work highlight, once again, the need for creating a long-term strategy for advancing deep-sea scientific knowledge to fill many of the knowledge gaps and contribute with scientific data to inform the development of policies that promote the sustainable use of deep-sea natural resources and support Maritime Spatial Planning. Such long-term strategies should translate into a clear effort to increase scientific knowledge of the Azores deep sea, notably by continuing efforts to map the Azorean seafloor and the communities living there. However, this will only be possible if the Azores are provided with the appropriate infrastructures and technological means but also long-term, stable, and predictable scientific careers for current and future scientists.

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14. Supplementary information

14.1 *Additional systematic conservation planning scenarios outputs*

14.1.1 Restoring fish stocks of commercially important deep-sea benthic species: 30% target

Goal: restoring fish stocks of commercially important deep-sea benthic species in the Azores EEZ.

Planning area: “Data-rich”

Features considered:

- Important resources; commercially important deep-sea fish;
- Important areas, VME; 10 hydrothermal vent (Saldanha, Famous, Lucky Strike, Menez Hom and South Lucky Strike, Menez Gwen and Bubbylon, Luso, Don Joao de Castro, and South Kurchatov);
- Important areas, VME; 3 portion of the MAR (Western ridge, Ridge east of Gigante, Cavalo), nine seamount-like features (Oscar, Gigante, Cavala, Beta, Voador, Condor, south-east of Pico Island, Don João de Castro, and Formigas);
- Important areas, essential fish habitats; 2 seamounts (Sedlo and Hard Rock Café seamounts)
- Important areas, shallow and very deep seamounts; 11 shallow water seamounts (Açor 160m depth, Condor 190m depth, Don João de Castro 20m depth, Formigas 0m depth, Gigante 160m depth, 127 160m depth, Grande Norte 120m depth, Mar da Prata Norte 170m depth and Mar da Prata Sul 260m depth, Princesa Alice 40m depth, and Voador 230m depth) and two deep-seamounts in the “data-rich” area (both probably named São Mateus de fora; deeper than approx. 1400m depth).
- Important areas, near-natural areas; 1 seamount (Diogo Teive);
- Representativity; Geomorphic Management Units (GMU).

Constraint on existing marine reserves: not implemented.

Management and conservation target: 30%.

Configurations of priority areas: high, medium, and low clumping.

Cost models: area-based cost and fisheries-based cost

Summary of the outputs: In brief, these scenarios selected mostly the “locked-in” important areas along the MAR with only a few additions of priority (Figure 95, Figure 96). This is because the representation targets are only implemented for commercially important fish species (Figure 98) and 30% is achieved mostly with the “locked-in” important areas. In both the area-based cost and fisheries-based cost there is a great degree of overlap with existing fishing grounds (Figure 97).

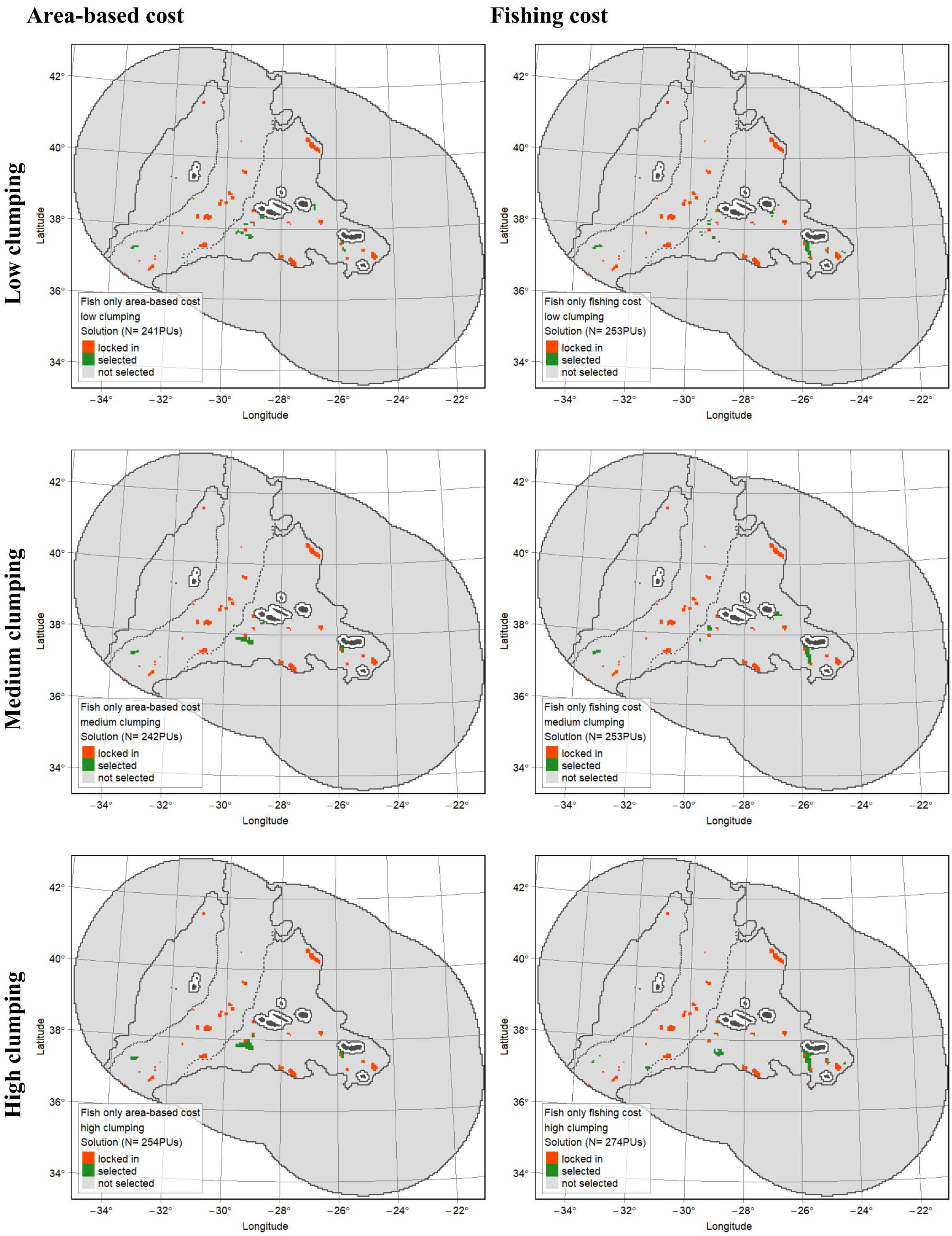

Figure 95. Prioritization solutions including the locked-in areas for the overarching goal of restoring fish stocks of commercially important deep-sea benthic species in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost models.

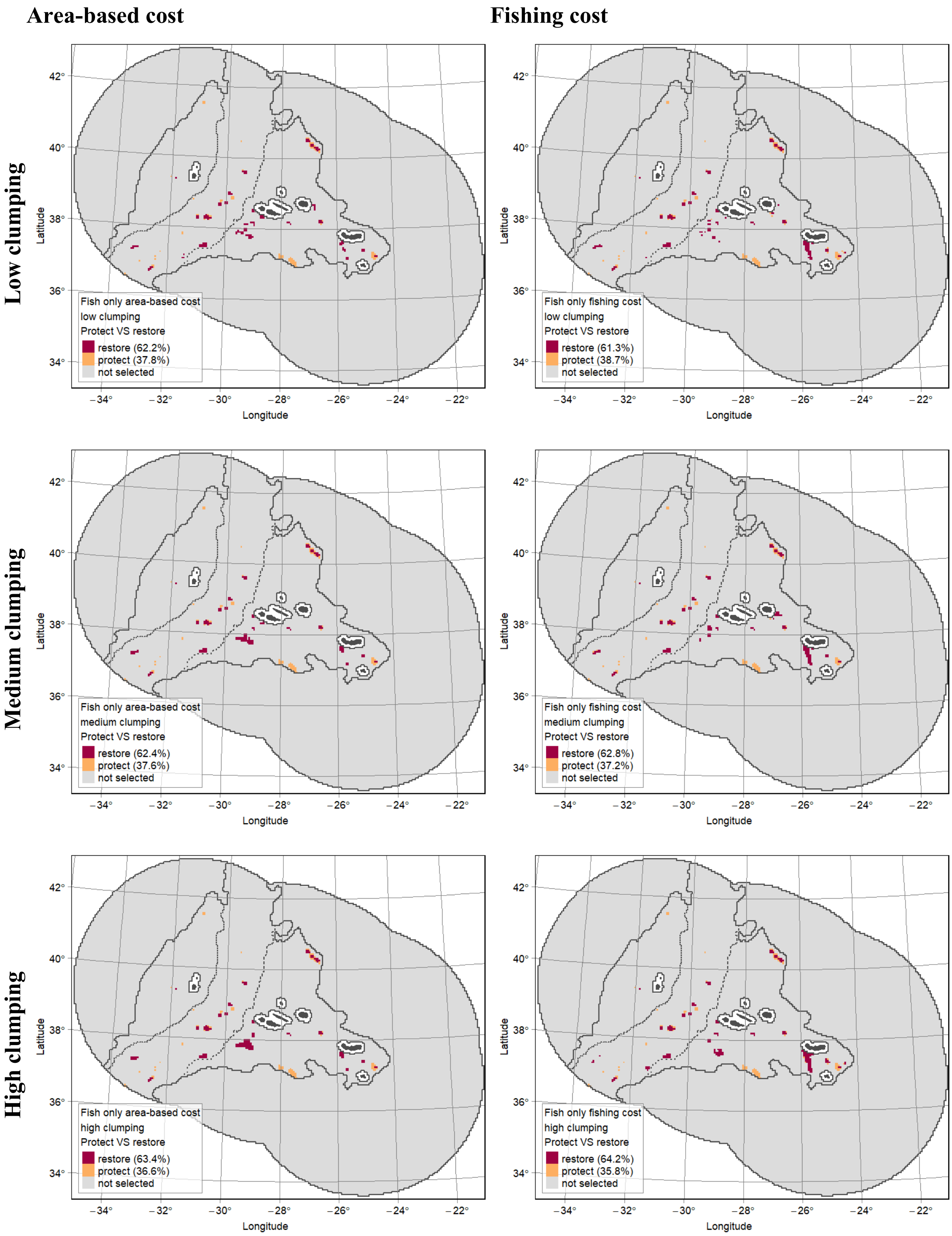

Figure 96. Prioritization solutions to 1) "protect" areas outside and 2) "restore" areas inside the present bottom fisheries footprint for the overarching goal of restoring fish stocks of commercially important deep-sea benthic species in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

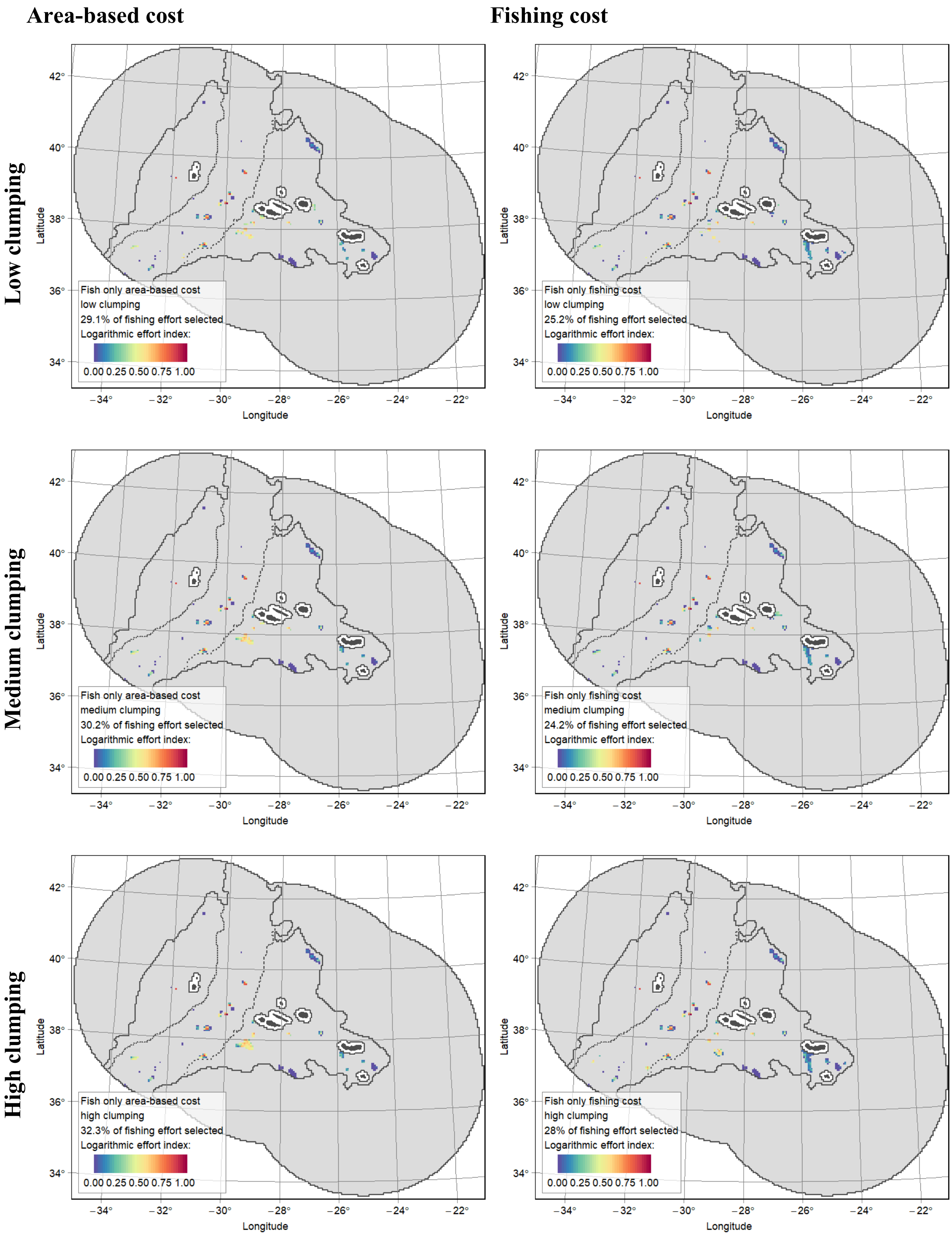

Figure 97. Fishing effort in the prioritization solutions for the overarching goal of restoring fish stocks of commercially important deep-sea benthic species in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

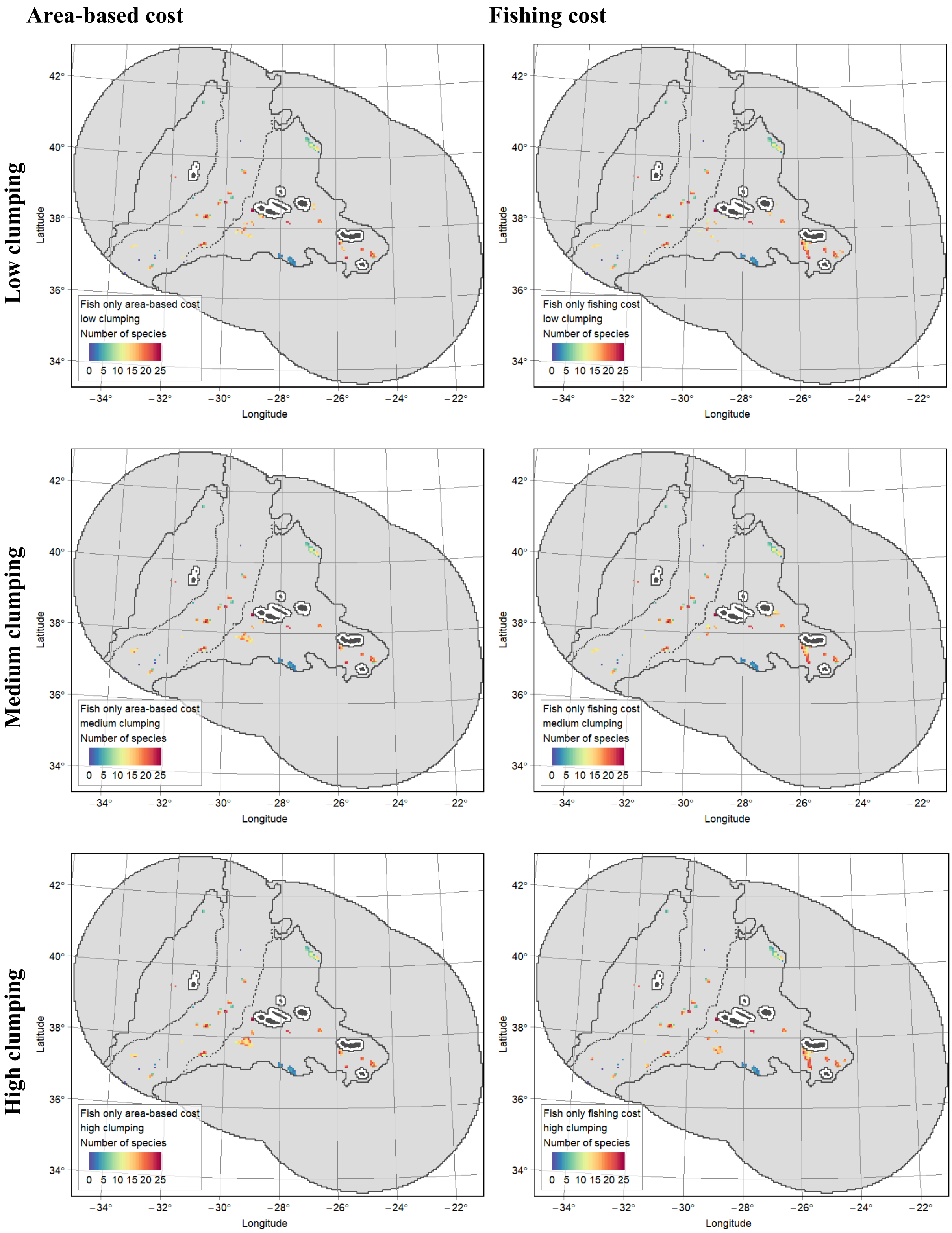

Figure 98. Number of features occurring in the prioritization solutions for the overarching goal of restoring fish stocks of commercially important deep-sea benthic species in the Azores with the scenario: 30% target, 3 different configurations (high, medium and low clumping), and fisheries-based cost. The areas with a 0 value contained only GMUs.

14.1.2 Ensuring protection and restoration of Vulnerable Marine Ecosystems: 30% target

Goal: ensuring protection of intact and restoration of degraded Vulnerable Marine Ecosystems in the Azores EEZ.

Planning area: "Data-rich"

Features considered:

- Important resources; inferred habitat-structuring CWC, inferred Vulnerable Marine Ecosystems, observed habitat-structuring CWC;
- Important areas, VME; 10 hydrothermal vent (Saldanha, Famous, Lucky Strike, Menez Hom and South Lucky Strike, Menez Gwen and Bubbylon, Luso, Don Joao de Castro, and South Kurchatov);
- Important areas, VME; 3 portion of the MAR (Western ridge, Ridge east of Gigante, Cavalo), nine seamount-like features (Oscar, Gigante, Cavala, Beta, Voador, Condor, south-east of Pico Island, Don João de Castro, and Formigas);
- Important areas, essential fish habitats; 2 seamounts (Sedlo and Hard Rock Café seamounts)
- Important areas, shallow and very deep seamounts; 11 shallow water seamounts (Açor 160m depth, Condor 190m depth, Don João de Castro 20m depth, Formigas 0m depth, Gigante 160m depth, 127 160m depth, Grande Norte 120m depth, Mar da Prata Norte 170m depth and Mar da Prata Sul 260m depth, Princesa Alice 40m depth, and Voador 230m depth) and two deep-seamounts in the "data-rich" area (both probably named São Mateus de fora; deeper than approx. 1400m depth).
- Important areas, near-natural areas; 1 seamount (Diogo Teive);
- Representativity; Geomorphic Management Units (GMU).

Constraint on existing marine reserves: not implemented.

Management and conservation target: 30%.

Configurations of priority areas: high, medium, and low clumping.

Cost models: area-based cost and fisheries-based cost

Summary of the outputs: Similar to the restoring fish stocks scenarios, these scenarios selected mostly the "locked-in" important areas along the MAR with only a few additions of priority areas (Figure 99, Figure 100). This is also because representation targets are only implemented for habitat-structuring CWC and Vulnerable Marine Ecosystems (Figure 102) and 30% coverage is achieved mostly with the "locked-in" important areas. In both the area-based cost and fisheries-based cost there is a great degree of overlap with existing fishing grounds (Figure 101).

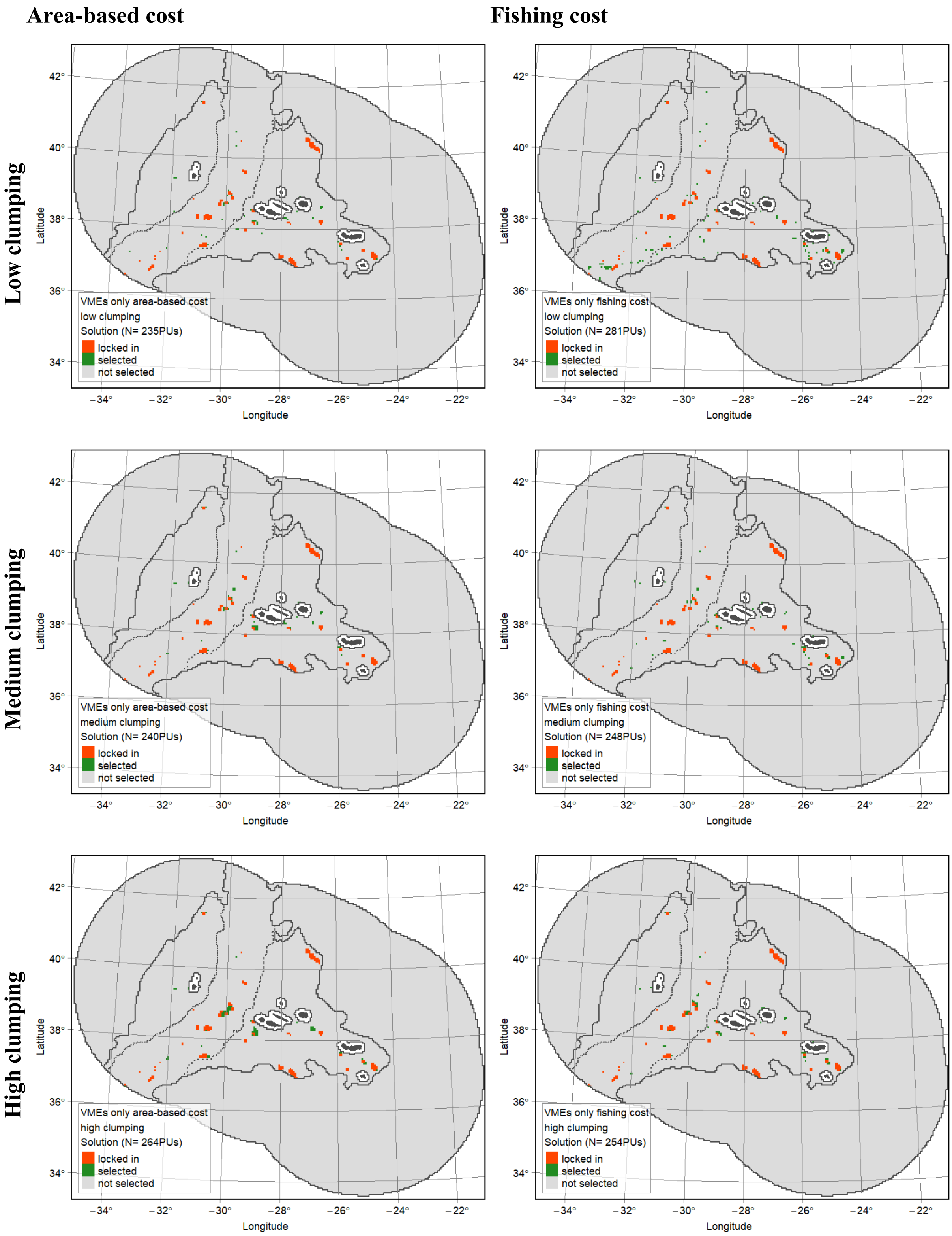

Figure 99. Prioritization solutions including the locked-in areas for the overarching goal of ensuring protection and restoration of Vulnerable Marine Ecosystems in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost models.

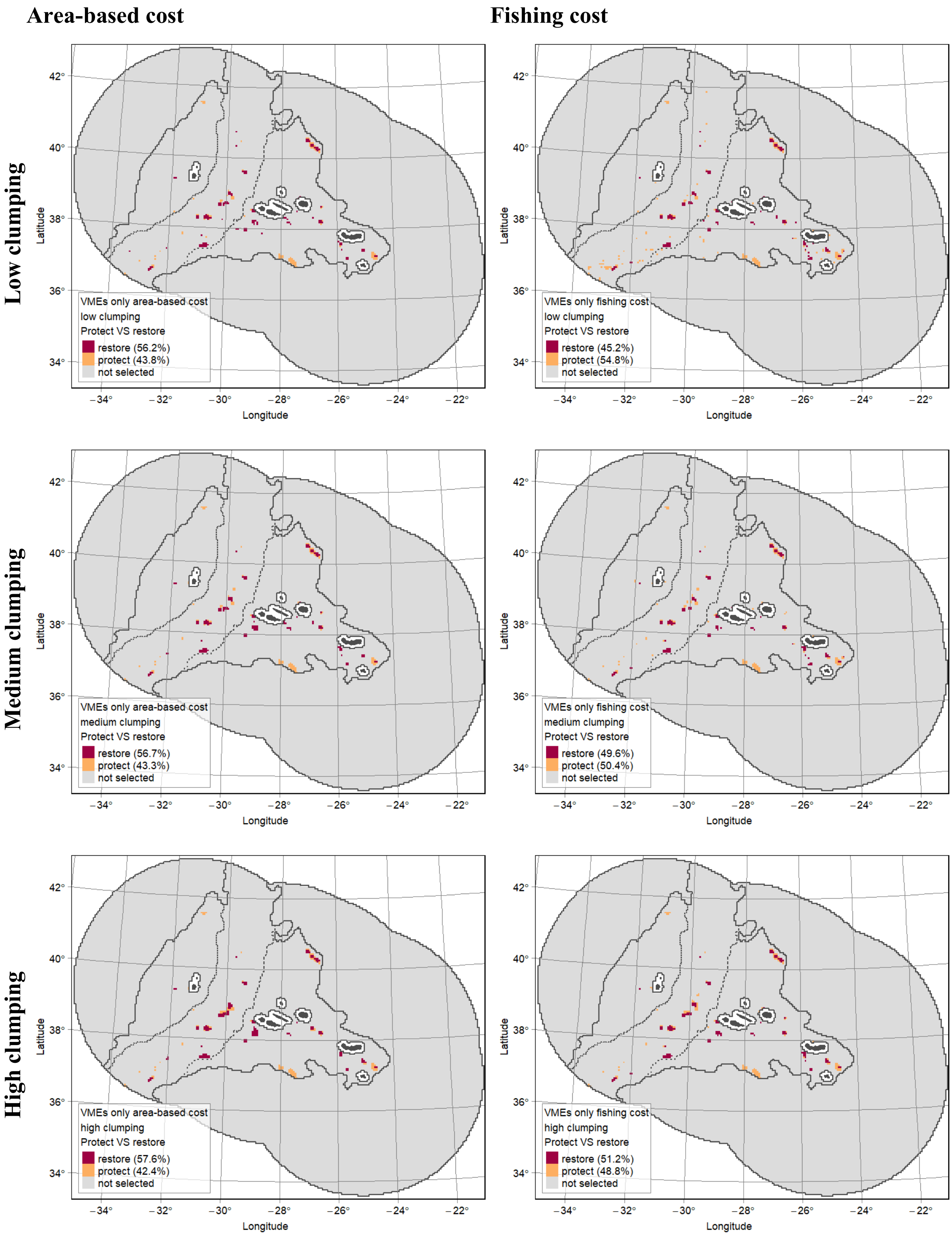

Figure 100. Prioritization solutions to 1) "protect" areas outside and 2) "restore" areas inside the present bottom fisheries footprint for the overarching goal of ensuring protection and restoration of Vulnerable Marine Ecosystems in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

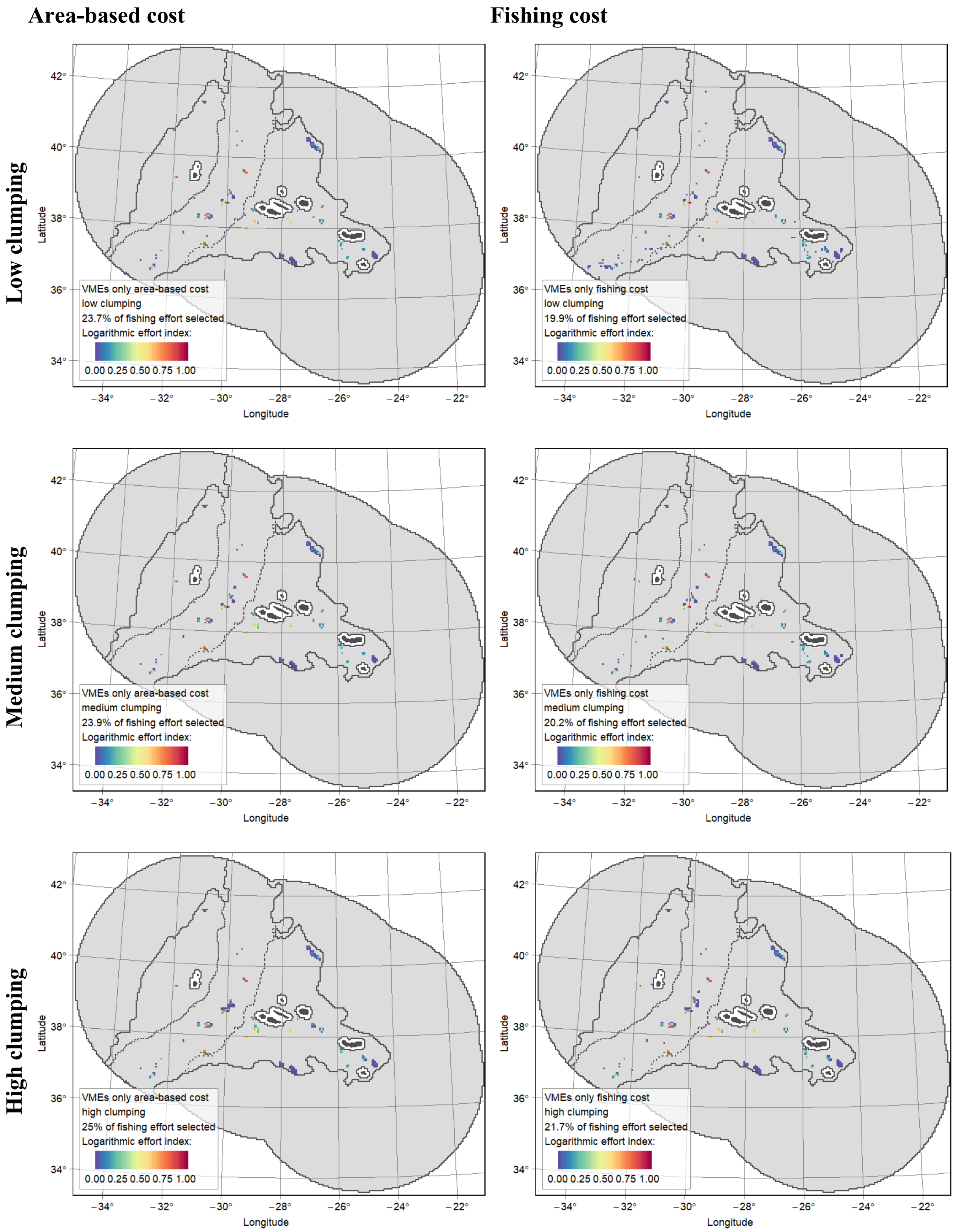

Figure 101. Fishing effort in the prioritization solutions for the overarching goal of ensuring protection and restoration of Vulnerable Marine Ecosystems in the Azores with the scenario: 30% spatial planning target, 3 different configurations (high, medium and low clumping), and area-based and fisheries cost.

Ensuring protection and restoration of Vulnerable Marine Ecosystems: 30%; Number of features

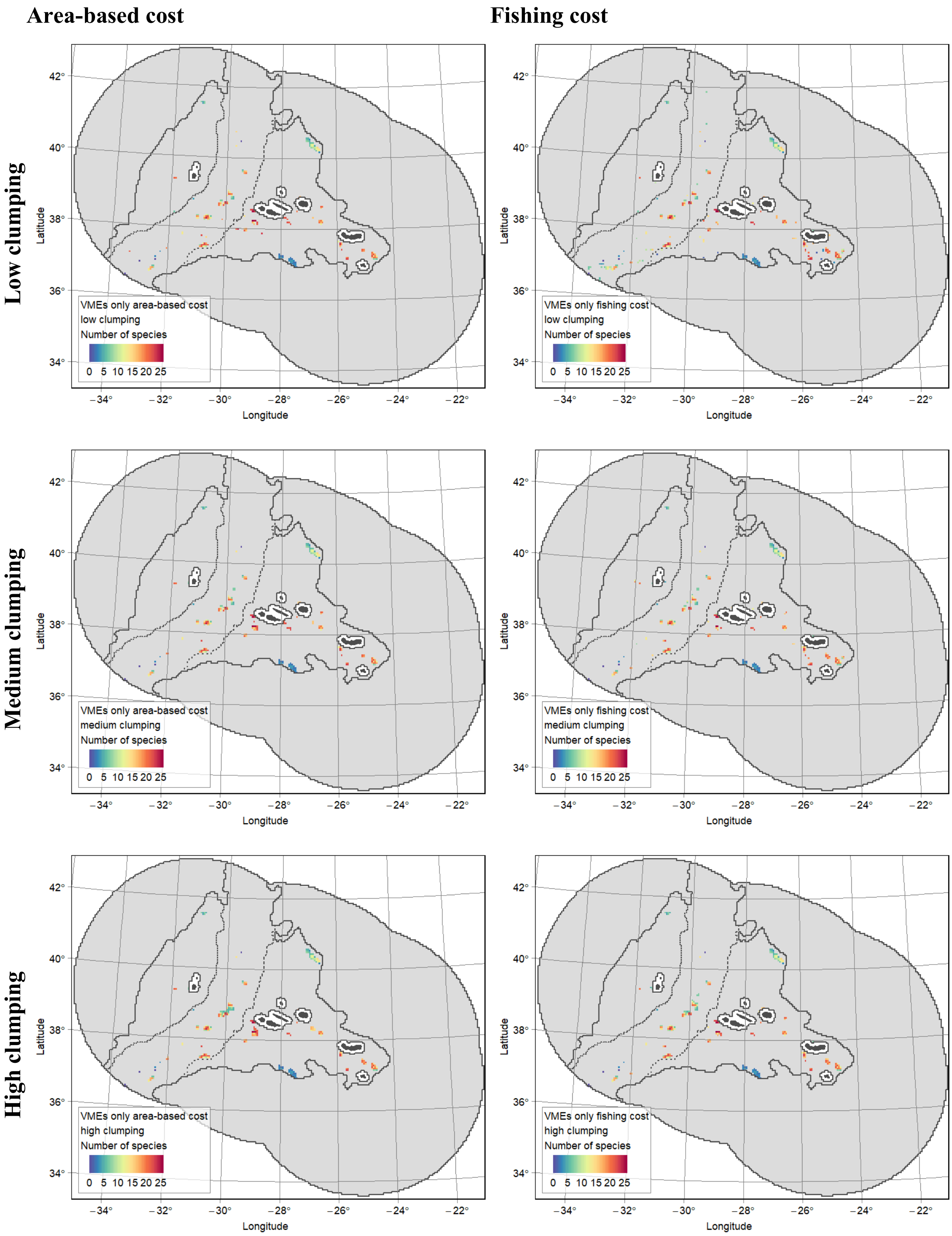

Figure 102. Number of features occurring in the prioritization solutions for the overarching goal of ensuring protection and restoration of Vulnerable Marine Ecosystems in the Azores with the scenario: 30% target, 3 different configurations (high, medium and low clumping), and fisheries-based cost. The areas with a 0 value contained only GMUs.

Appendix 1

An update of "Marine data to characterize the maritime space of the Azores - inventory of spatial data sets". In support of the Systematic conservation planning scenarios for achieving multiple management objectives in the deep-sea of the Azores

Luís Rodrigues[1,2], Cristina Gutiérrez-Zárate[1,2], Carlos Dominguez-Carrió[1,2], Gerald H. Taranto[1,2], Laurence Fauconnet[1,2], Manuela Ramos[1,2], Jordi Blasco-Ferre[1,2], Christopher K. Pham[1,2], Ana Colaço[1,2], José M. Gonzalez-Irusta[1], Eva Giacomello[1,2], Marina Carreiro-Silva[1,2], Telmo Morato[1,2]

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Appendix 2

Multidisciplinary characterization of the new Luso hydrothermal vent field (Mid-Atlantic Ridge, Azores)

Telmo Morato[1], Marina Carreiro-Silva[1], A. Filipa A. Marques[2], Teresa Cerqueira[1], Carlos Dominguez-Carrió[1], Ágata Alvarinho Dias[3], Ana Colaço[1], António Calado[4], Luís Rodrigues[1], Mustafa Yücel[5], Cédric Boulard[6], Erwan Peru[7], Luísa Ribeiro[4], Pedro Madureira[4], Emanuel Gonçalves[8], Nadine Le Bris[7]

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[2] University of Bergen, Norway
[3] University of Saint Joseph (ISE-USJ), Macau
[4] Task Group, Extension of the Continental Shelf, Portugal
[5] Middle East Technical University, Mersin, Turkey
[6] Sorbonne Universités, Roscoff, Franc
[7] CNRS, Sorbonne Université, Banyuls-sur-Mer, France
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Appendix 3

Deep-sea benthic communities inhabiting various geomorphological features in the Azores

Carlos Dominguez-Carrió[1,2], Marina Carreiro-Silva[1,2,*], Jordi Blasco-Ferre[1,2], Manuela Ramos[1,2], Gerald H. Taranto[1,2], Luís Rodrigues[1,2], Cristina Gutiérrez-Zárate[1,2], Marina Carreiro-Silva[1,2], Telmo Morato[1,2,*]

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[*] These authors contributed equally to the overall scientific strategy resulting in this is work

Appendix 4

Dives with LULA1000 in Baixo de São Mateus

, Marina Carreiro-Silva[1,2], Carlos Dominguez-Carrió[1,2], Jordi Blasco-Ferre[1,2], Luís Rodrigues[1,2], Telmo Morato[1,2]

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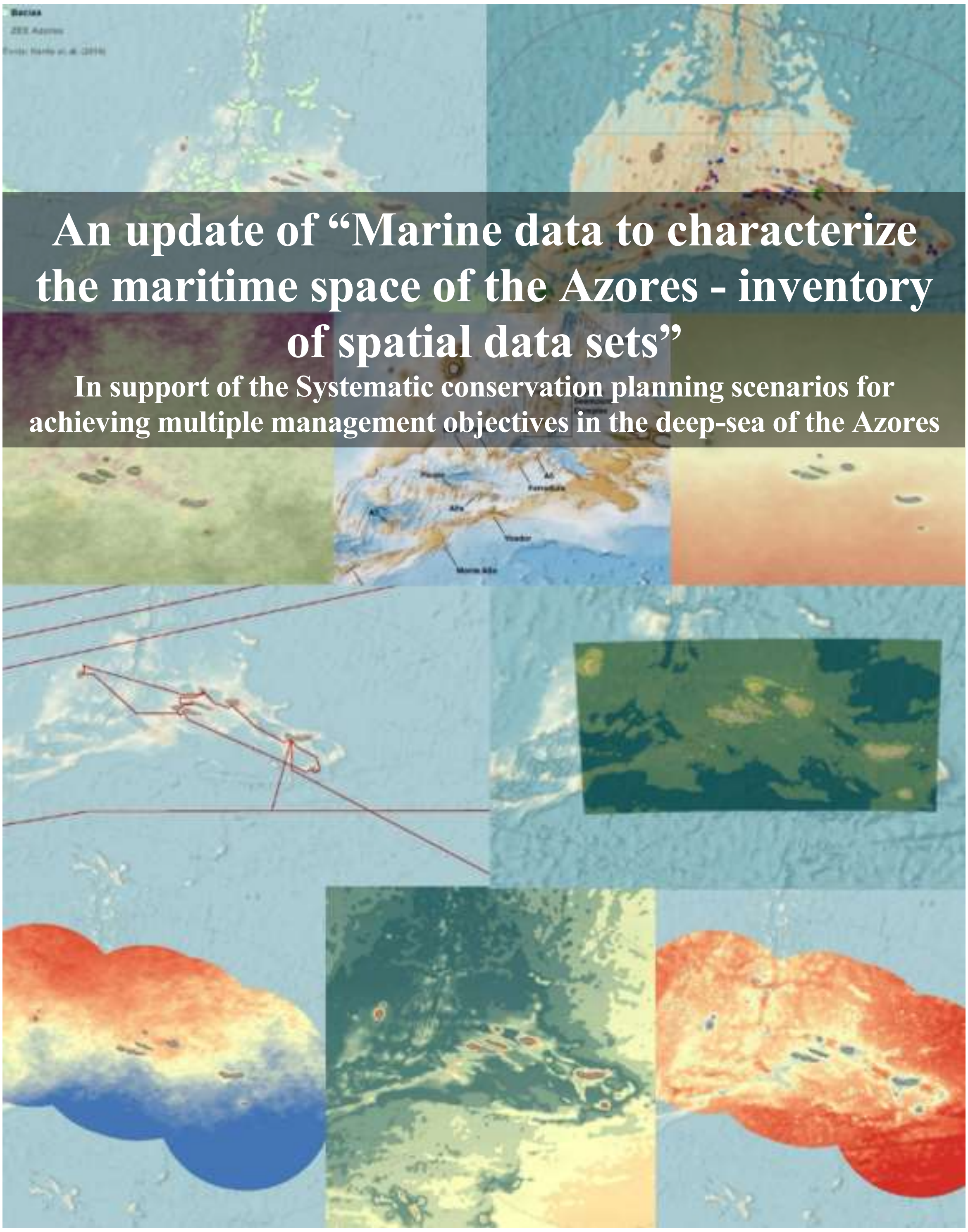
Morato, T., Combes, M., Brito, J., Rodrigues, L., Dominguez-Carrió, C., Taranto, G.H., Fauconnet, L., Ramos, M., Blasco-Ferre, J., Gutiérrez-Zárate, C., Pham, C.K., Colaço, A., Gonzalez-Irusta, J.M., Giacomello, E., & Carreiro-Silva, M. (2020) Systematic conservation planning scenarios for the Azores deep-sea: draft v.11 Feb 2020. Okeanos Centre of the University of the Azores, Horta, Portugal.



An update of “Marine data to characterize the maritime space of the Azores - inventory of spatial data sets”

In support of the Systematic conservation planning scenarios for achieving multiple management objectives in the deep-sea of the Azores

Luís Rodrigues[1,2], Cristina Gutiérrez-Zárate[1,2], Carlos Dominguez-Carrió[1,2], Gerald H. Taranto[1,2], Laurence Fauconnet[1,2], Manuela Ramos[1,2], Jordi Blasco-Ferre[1,2], Christopher K. Pham[1,2], Ana Colaço[1,2], José M. Gonzalez-Irusta[1], Eva Giacomello[1,2], Marina Carreiro-Silva[1,2], Telmo Morato[1,2]

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23 November 2023

Contributed to MarSP Deliverable: D.3.5. Spatial distribution maps of species, habitats and impacts

Index

Table list

Acronym list

DRAM	Direção Regional dos Assuntos do Mar
EU	European Union
MSP	Maritime Spatial Planning
SRMCT	Secretaria Regional do Mar, Ciência e Tecnologia
VME	Vulnerable Marine Ecosystems
DTM	Digital Terrain Model
DEM	Digital Elevation Model
CWC	Cold-water Corals
DWS	Deep-water Sharks
NASA	National Aeronatics and Space Administration
NOAA	National Oceanic and Atmospheric Administration

Introduction

One of the most important stages in systematic conservation planning is to compile the best available data on the biological and environmental conditions, and human uses in the planning area. A special focus should be given to collect information that would specifically address the agreed management goals and objectives. After the first expeditions to the deep sea in the late 19th and early 20th centuries lead by Prince Albert I of Monaco, extensive scientific research based in the Azores has opened a window on the functioning of large open-ocean and deep-sea ecosystems and on the impacts of human activities in such ecosystems. These efforts have contributed with large amounts of data useful to characterize the maritime space of the Azores and to inform maritime spatial planning or systematic conservation planning exercises.

Here, we present the most recent compilation of georeferenced data of the maritime space of the Azores. This compilation started back in 2007/2008 with the FP7 Hermione and CoralFISH projects and had a great boost during the project "2020: Towards ecosystem-based management of the Azores marine resources, biodiversity and habitats" funded by the Regional Government of the Azores. More recently, both the PO2020-Açores MapGES project and the H2020 ATLAS projects have helped to increase the data available, mostly for the deep waters of the Azores. This compilation is an update of a data compilation produced for the EASME/EMFF MarSP Macaronesian Maritime Spatial Planning project. In this framework we structured, compiled, organised and updated spatial data of oceanographic information (physical and chemical parameters), biodiversity (species and habitats, including classified) geomorphology, and human activities at sea. We collated spatial datasets and respective metadata, relative to the following topics:

- Geomorphology/ Bathymetry;
- Oceanography (physical, chemical and hydrological parameters);
- Biodiversity (biological characterisation focused on special relevance areas for conservation, including the observed and/or predicted distribution of classified species; marine and coastal habitats and biotopes, including the classified ones);
- Pressures and impacts of human activities on ecosystems;
- Uses and human activities;
- Legal issues.

Most of this data will be integrated in Geographical Information System (GIS) for the marine environment of the Azores, the SIGMAR-Açores as .tif image format for the matrix data models and shapefile for the vectorial data models. These were the required formats by the DRAM within its competences and attributions regarding Maritime Spatial Planning, integral and sustainable management of maritime space, conservation and protection of resources and geographical information management about marine ecosystems.

Inventory of Spatial Data Sets

In this point, the main processes inherent to the compilation, organization and update of spatial datasets are presented and structured in six topics:

1. Geomorphology / Bathymetry;
2. Oceanography (physical and chemical parameters);
3. Biodiversity (Species and habitats);
4. Pressures and impacts of human activities on ecosystems;
5. Uses and human activities;
6. Legal issues.

To this effect, all spatial datasets are identified according to:

1. Type of data;
2. File size;
3. Data production year;
4. Keywords;
5. Summary;
6. Data description (acquisition methodology, authorship, data observation year, localization, etc.);
7. Credits;
8. Use restrictions;
9. Extent (North, South, East, West – geographical coordinates);
10. Citation Contact;
11. Point of Contact;
12. Spatial Reference.

1. Inventory of Spatial Data Sets: Geomorphology/ Bathymetry

The collection of topics about geomorphology of the Azorean Sea includes very diverse information about the type of seabed of the Region. Information about bathymetry and related matters, the localization of specific physiographical structures such as seamounts, canyons, ridges or hydrothermal vents and even information about sediment type can be found here.

Topic	Spatial Data Sets	Spatial Data Type	Year (last update)
Azores Bathymetry	Azores Bathymetry	Raster	2019
Seamounts	Seamounts	Vectorial Points	2019
Hydrothermal vents	Hydrothermal vents	Vectorial Points	2019
Seafloor Geomorphologic maps	Abyssal Plains	Vectorial Polygons	2014
	Submarine Basins	Vectorial Polygons	2014
	Canyons	Vectorial Polygons	2014
	Scarps	Vectorial Polygons	2014
	Plateaus	Vectorial Polygons	2014
	Ridges	Vectorial Polygons	2014
	Rift valleys	Vectorial Polygons	2014
	Shelf classification	Vectorial Polygons	2014
	Slopes	Vectorial Polygons	2014
	Mid-Atlantic Ridges	Vectorial Polygons	2014
	Troughs	Vectorial Polygons	2014

Table 1. Spatial Data Sets of Geomorphology and Bathymetry.

1.1. Azores Bathymetry

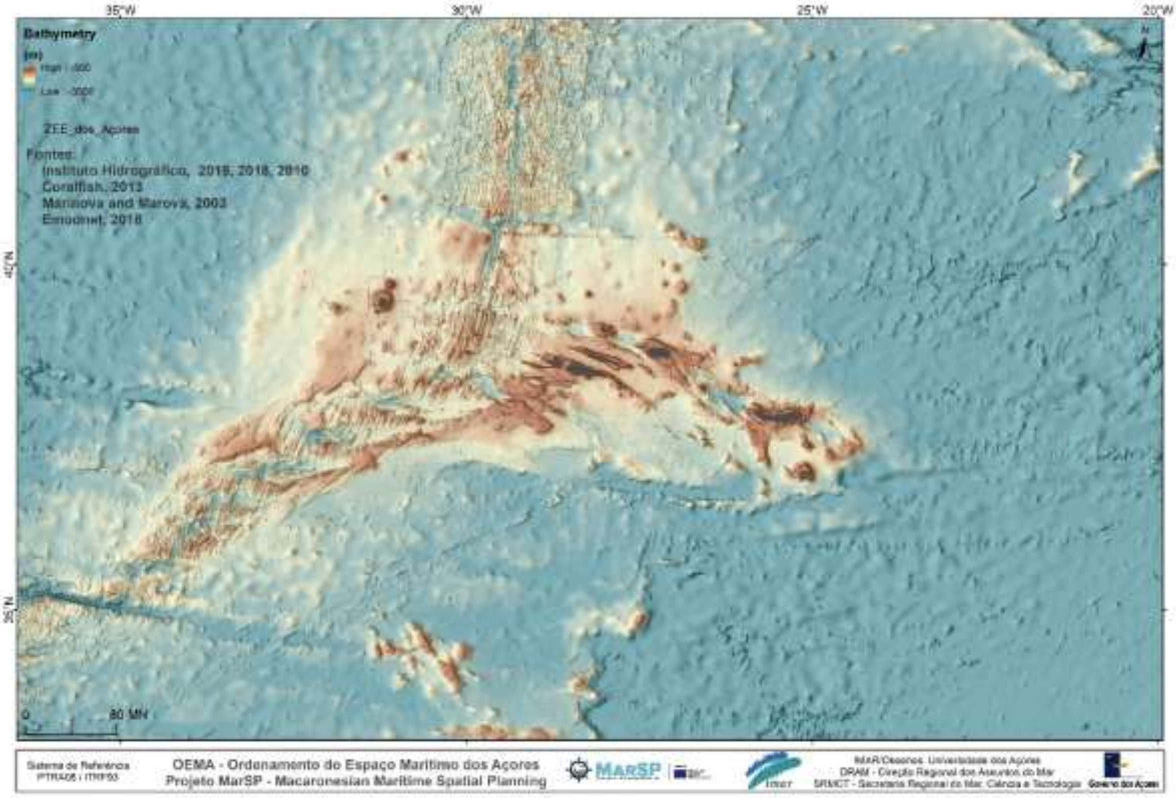
Raster Dataset: 100m (1.21 GB)

Year: 2019

Keywords: multibeam, bathymetry, Azores, digital elevation model

Summary: Mosaicking the Digital Elevation Model in the Azores ZEE with the best bathymetry available in 2019 with 100m grid cell-size.

Bathymetry of the Azores, 2019



Description: Mosaicking the Digital Elevation Model in the Azores ZEE with the best bathymetry available in 2019 with 100m grid cell-size.

Here we compiled the best available bathymetry data to generate the most detailed digital elevation model. The model prioritizes data from higher to lower resolution.

For example, it includes the most recent 2019 multibeam data from Instituto Hidrográfico (IH).

The EMODNET 2018 bathymetry is an input for the areas in the EEZ of the Azores without multibeam coverage from other sources.

The list of multibeam sources are:

- Instituto Hidrográfico, 2019. Multibeam data (NRP D. Carlos I) with multiple resolutions between 8m to 128m covering the South Flores seamounts, Sarda seamount, North Sarda seamount, Diogo de Teive seamount, Cabeço and Picos SW Flores.
- NIOZ, 2018-2019 (2018 - São Jorge de Fora 64PE441; 2019 - Sarda 64PE454, Rainbow 64PE454, SE PICO 64PE454, São Jorge de Fora 64PE456), Data Acquisition. Instituto Hidrográfico, 2019, Data Treatment. Multibeam data with multiple resolutions between 16m to 128m covering the areas of Rainbow, São Jorge de Fora, Sudeste Pico, Sarda, Transit between Rainbow and São Jorge de Fora.
- Instituto Hidrográfico, 2018. Multibeam data (NRP Almirante Gago Coutinho) with multiple resolutions between 4m to 128m covering the areas around Flores and Corvo, the Cachalote seamount, Gigante seamounts, Princesa Alice seamount.
- METEOR-Berichte, 2015. Multibeam data with various resolutions from 16 to 256m covering many areas around Azorean EEZ.

- Coralfish project, 2013. Multibeam data with the resolution of the 10m covering the area of Princesa Alice, Voador, Condor and around Terceira island.
- MARINOVA and MAROV projects, 2003. Multibeam data with the resolution of the 10m covering the area around Faial, Pico, São Jorge islands.
- Instituto Hidrográfico, 2010. Multibeam data with the resolution of the 10m covering the area around Faial island and Condor seamount.
- Emodnet, 2018. The elevation model as a base to cover nodata available from multibeam.

Credits: IMAR, Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.806713 East -19.631566

North 43.553066 South 33.132166

Citation Contacts:
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CONTACT'S ROLE Principal Investigator
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Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
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1.2. Seamounts

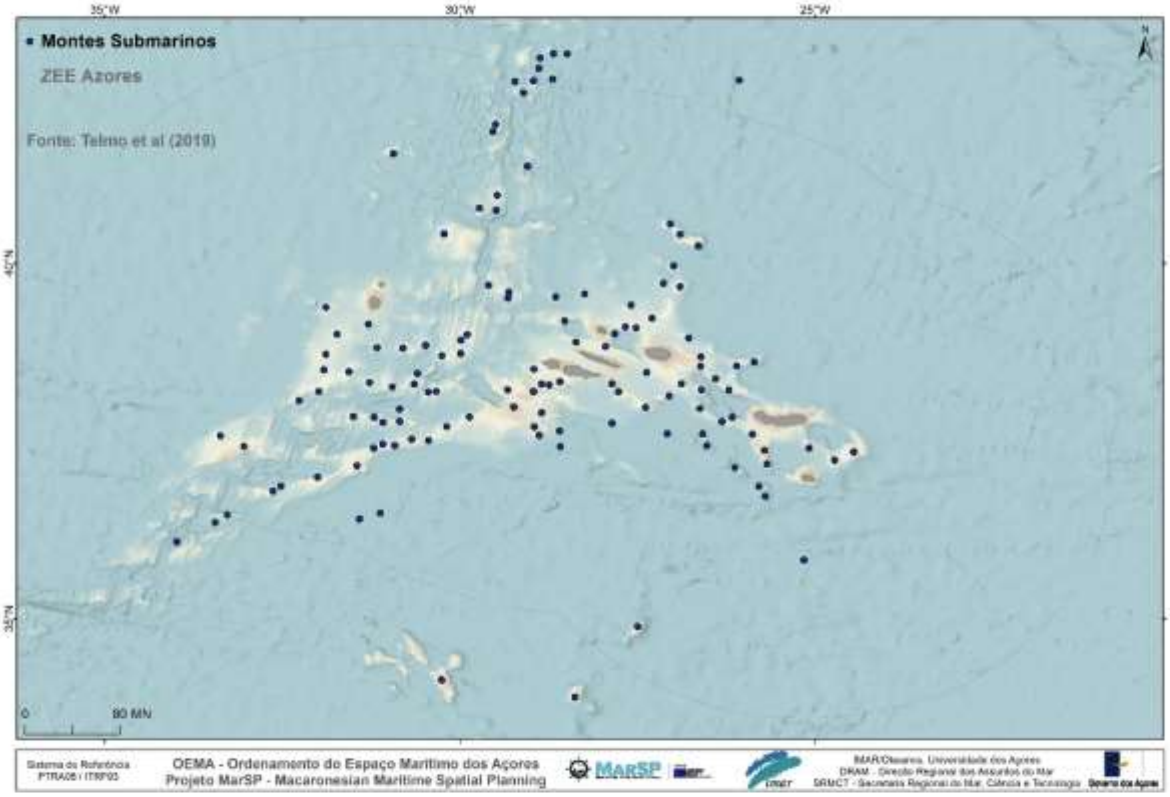
Shapefile: Points (1:5 000 000)

Year: 2019

Keywords: North Atlantic Ocean, Europe, Portugal, Azores islands, geology, geomorphology, seafloor

Summary: This layer provides geographic information related to the abundance and distribution of seamounts of the economic exclusive zone (EEZ) in the Azores.

Geomorphology: Seamounts of the EEZ of the Azores



Description: This geographic information related to the abundance and distribution of seamounts of the Azores. A total of 63 large and 398 small seamount-like features are mapped and described in the Azorean EEZ. The distribution of seamount extracted from this source published in 2008 predicts that about 57% of the potential Azores seamounts lie in the zone protected from deep-water trawling by European Commission Council Regulation No. 1568/2005.

Reference: Morato T.; M. Machete; A. Kitchingman; F. Tempera; S. Lai; G. Menezes; R. S. Santos; and T.J. Pitcher (2008). Abundance and distribution of seamounts in the Azores. Marine Ecology Progress Series 357: 23-32

Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -33.991860 East -24.453122

North 42.944509 South 33.248340

Citation Contacts:
INDIVIDUAL'S NAME Telmo Morato
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Researcher
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS telmo.af.gomes@uac.pt

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
CONTACT'S ROLE point of contact
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -10395.877887999999
Z SCALE 524288000244.1405
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

1.3. Hydrothermal vents

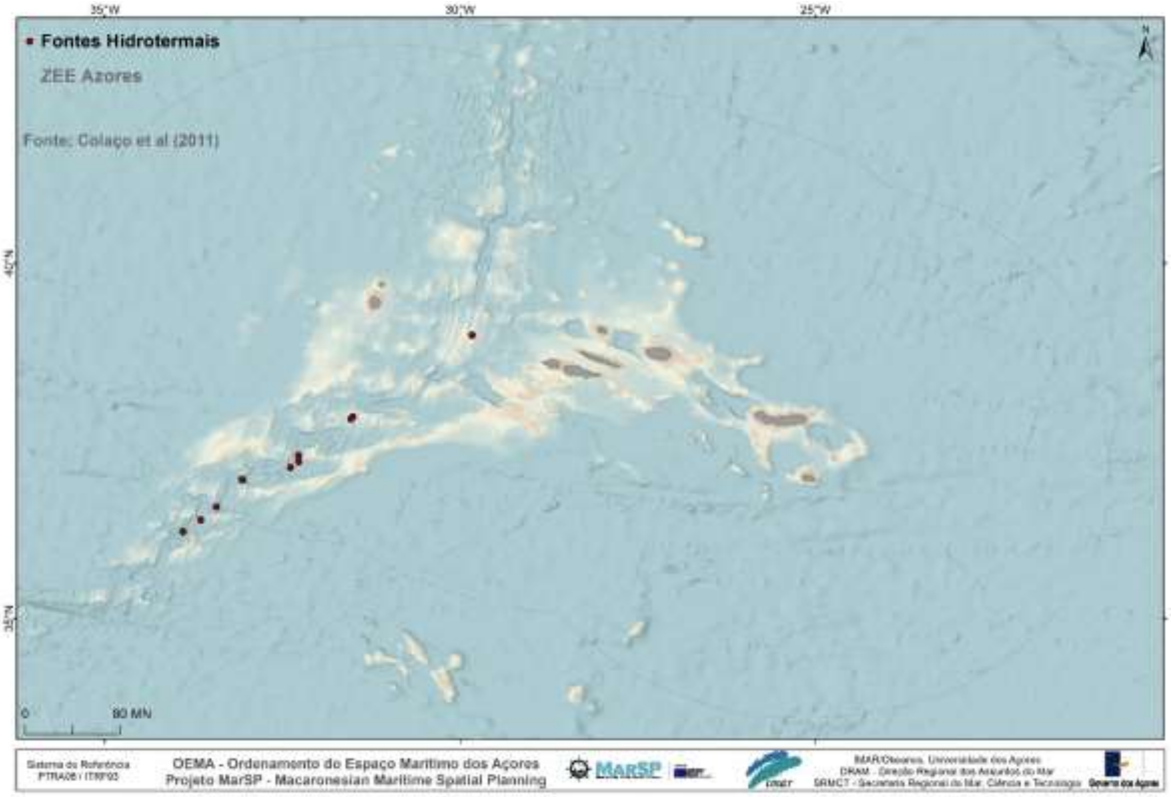
Shapefile: Point (1:5 000 000)

Year: 2019

Keywords: Azores, ecology, chemical, hydrothermal, monitoring, ocean, seafloor, vent

Summary: This layer provides geographic information related to the location of the hydrothermal vents in the Mid-Atlantic Ridge, in the Azores.

Geomorphology: Hydrothermal vents of the EEZ of the Azores



Description: The Mid-Atlantic Ridge near the Azores consists of different known hydrothermal vent fields. Each one presents specific geological, chemical, hydrothermal and biological characteristics. Hydrothermal circulation at mid-ocean ridges is a basic process that impacts the transfer of energy and matter from the interior of the Earth to the crust, hydrosphere and biosphere.

Reference: Colaço, A., Blandin, J., Cannat, M., Carval, T., Chavagnac, V., Connelly, D., Fabian, M., Ghiron, S., Goslin, J., Miranda, J. M., Reverdin, G., Sarrazin, J., Waldmann, C., and Sarradin, M. 2011. MoMAR-D: a technological challenge to monitor the dynamics of the Lucky Strike vent ecosystem. ICES Journal of Marine Science, 68: 416–424

On this layer, we represent the following 11 hydrothermal vents:

- Menez Gwen;
- Lucky Strike;
- Ewan;
- Saldanha;
- Rainbow;
- Menez Hom;
- Famous;
- Bubbylon;
- Amar;
- Evan;
- Luso.

Credits: IMAR/Okeanos. University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -33.900751 East -29.834445
North 38.983924 South 36.216600

Citation Contacts:
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
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CONTACT'S POSITION Marine Biologist Researcher
E-MAIL ADDRESS acolaco@uac.pt

Point of Contact:
INDIVIDUAL'S NAME Luís Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
*TYPE Projected
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details
Projected coordinate system
Well-known identifier 3395
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552

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Z SCALE 10000
M ORIGIN -100000
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XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 3395

WELL-KNOWN TEXT
PROJCS["WGS_1984_World_Mercator",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["False_Easting",0.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",0.0],PARAMETER["Standard_Parallel_1",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",3395]]

1.4. Seafloor geomorphologic maps

Shapefile series (11 polygons or point files).

These 11 layers are part of the 25 layers that make up the global seafloor geomorphologic features map (Harris et.al. 2014). These 11 layers was created by clipping main layers representing the ocean by subject:

- Abyssal plains classification;
- Submarine basins;
- Canyons;
- Scarps;
- Plateaus;
- Ridges;
- Rift valleys;
- Shelf classification;
- Slopes;

- Mid-Atlantic ridges;
- Troughs.

1.4.1. Abyssal Plains

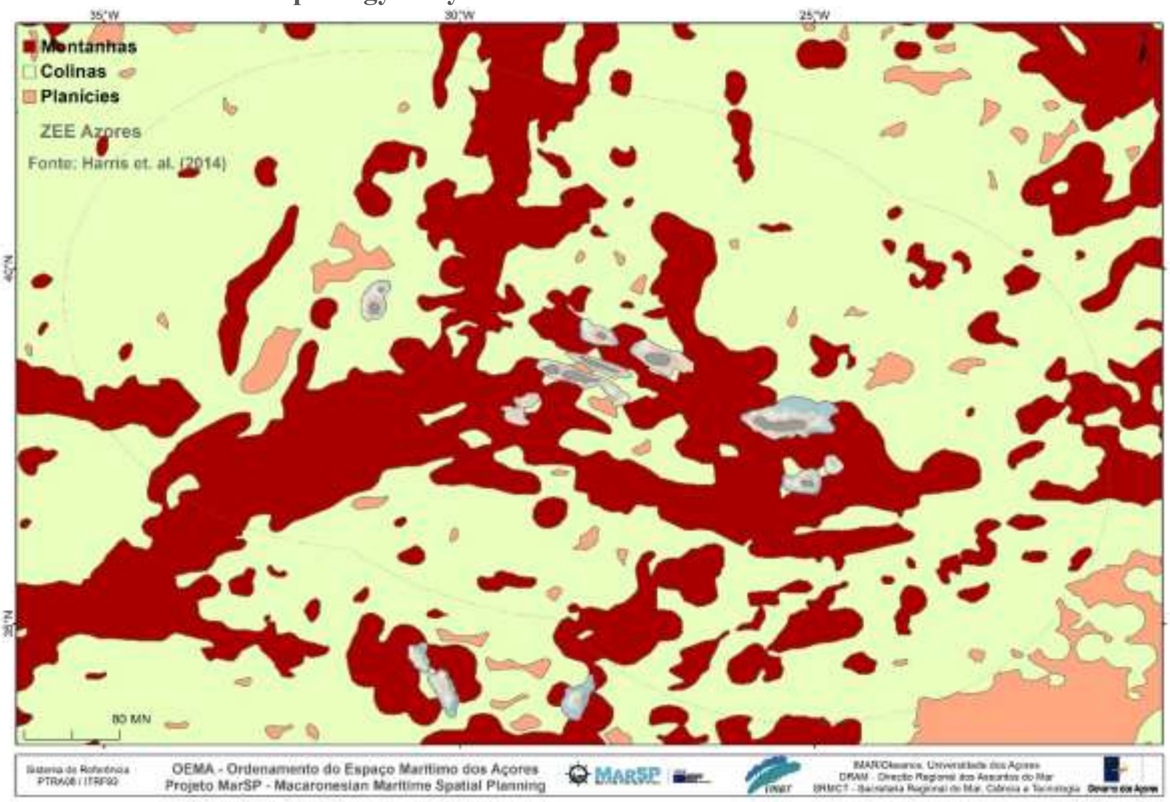
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, abyssal classification, hills, mountains, plains, habitat

Summary: The abyss classification geomorphic feature layer represents the spatial extend of the abyssal plain, hill and mountain areas of Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic feature maps are intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Abyssal classification of the EEZ of the Azores



Description: The abyssal classification geomorphic feature layer represents the spatial extent of the abyssal areas of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). The abyss is the area of seafloor located at depths below the foot of the continental slope and above the depth of the hadal zone (defined as deeper than 6,000 m). The abyssal classification feature layer was created by clipping a layer representing the ocean with the shelf, slope and hadal layers. The resulting layer was then classification into areas of plains, hills and mountains based on variation in topography.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
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Y ORIGIN -400
XY SCALE 11258999068426.238
identifier 4326
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Point of Contact:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no
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Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known

1.4.2. Submarine basins

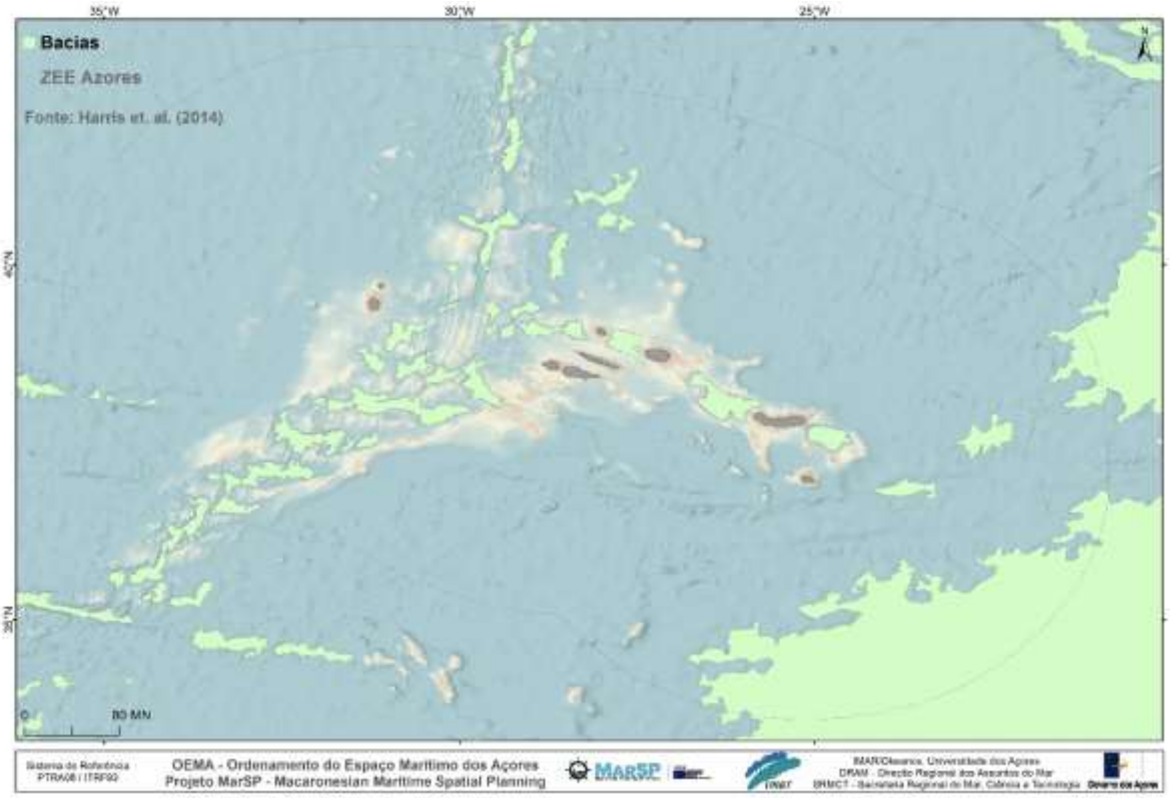
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, basin, habitat

Summary: The basin geomorphic feature layer represents the spatial extent of the submarine basins of the Azores region, interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Submarine basins of the EEZ of the Azores



Description: The basin geomorphic feature layer represents the spatial extent of the submarine basins of the Azores, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). Basins are “a depression, in the sea floor, more or less equidimensional in plan and of variable extent” (IHO, 2008). In this study basins are restricted to seafloor depressions that are defined by closed bathymetric contours. Basins were mapped based on the identification of the most shoal, closed, bathymetric contours, examined regionally for the major ocean basins and shelf seas.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
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Point of Contact:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
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M SCALE 10000
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Left longitude -180
Latest well-known identifier 4326
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1.4.3. Canyons

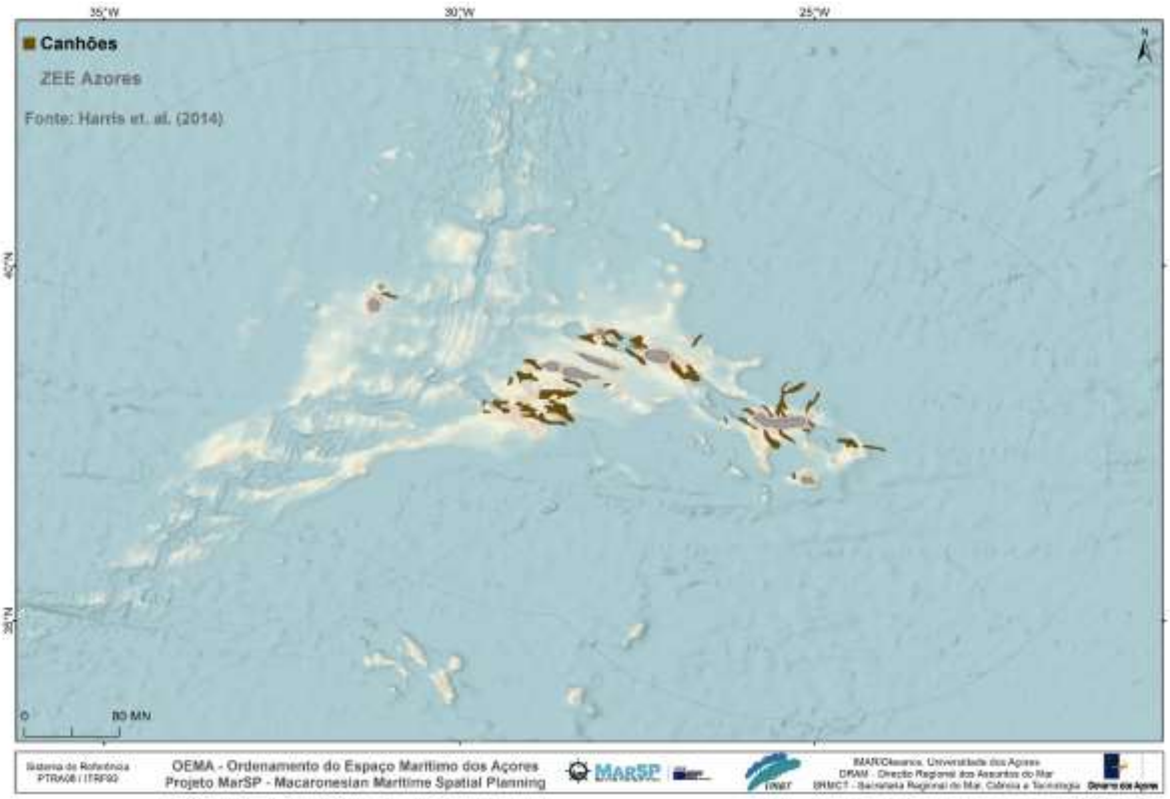
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, canyon, habitat

Summary: The canyon geomorphic feature layer represents the spatial extent of the submarine canyons of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Canyons of the EEZ of the Azores



Description: The canyon geomorphic feature layer represents the spatial extent of the submarine canyons of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). Submarine canyons are defined as “steep-walled, sinuous valleys with V-shaped cross sections, axes sloping outward as continuously as river-cut land canyons and relief comparable to even the largest of land canyons” (Shepard, 1963). “Large” canyons were mapped in this study based on the definition of Harris and Whiteway (2011), which requires canyons to extend over a depth range of at least 1,000 m and to be incised at least 100 m into the slope at some point along their thalweg. Canyon mapping in this study was based on a combination of automated and expert interpretation of the SRTM30PLUS model.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Point of Contact:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
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1.4.4. Scarps

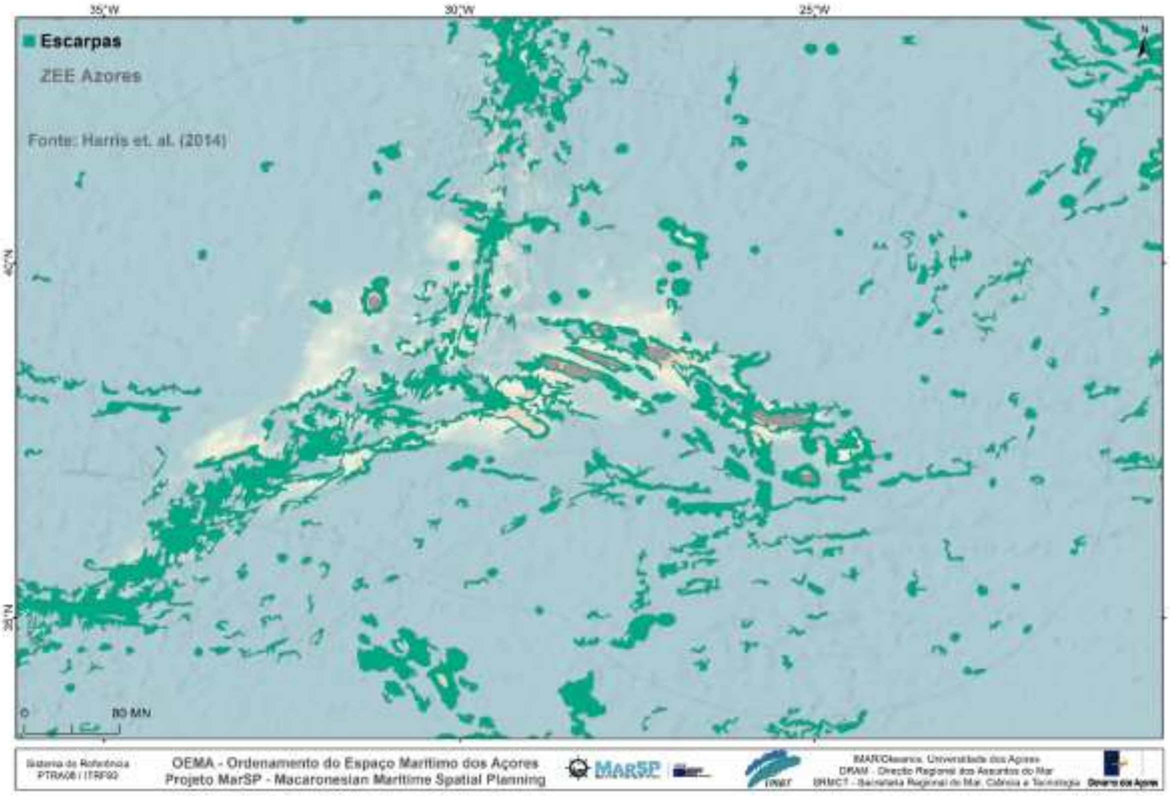
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, escarpment, habitat

Summary: The escarpment geomorphic feature layer represents the spatial extent of the escarpments of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Scarps of the EEZ of the Azores



Description: The escarpment geomorphic feature layer represents the spatial extent of the escarpments of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). Escarpments are “an elongated, characteristically linear, steep slope separating horizontal or gently sloping sectors of the sea floor in non-shelf areas. Also abbreviated to scarp” (IHO, 2008). Escarpments, like basins, overlay other features (i.e. other individual features may be partly or wholly covered by escarpments). Thus, features like the continental slope, seamounts, guyots, ridges and submarine canyons (for example) may be sub-classified in terms of their area of overlain escarpment. Escarpments were calculated based on the gradient of the SRTM30_PLUS model.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Point of Contact:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
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M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
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High precision true
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1.4.5. Plateaus

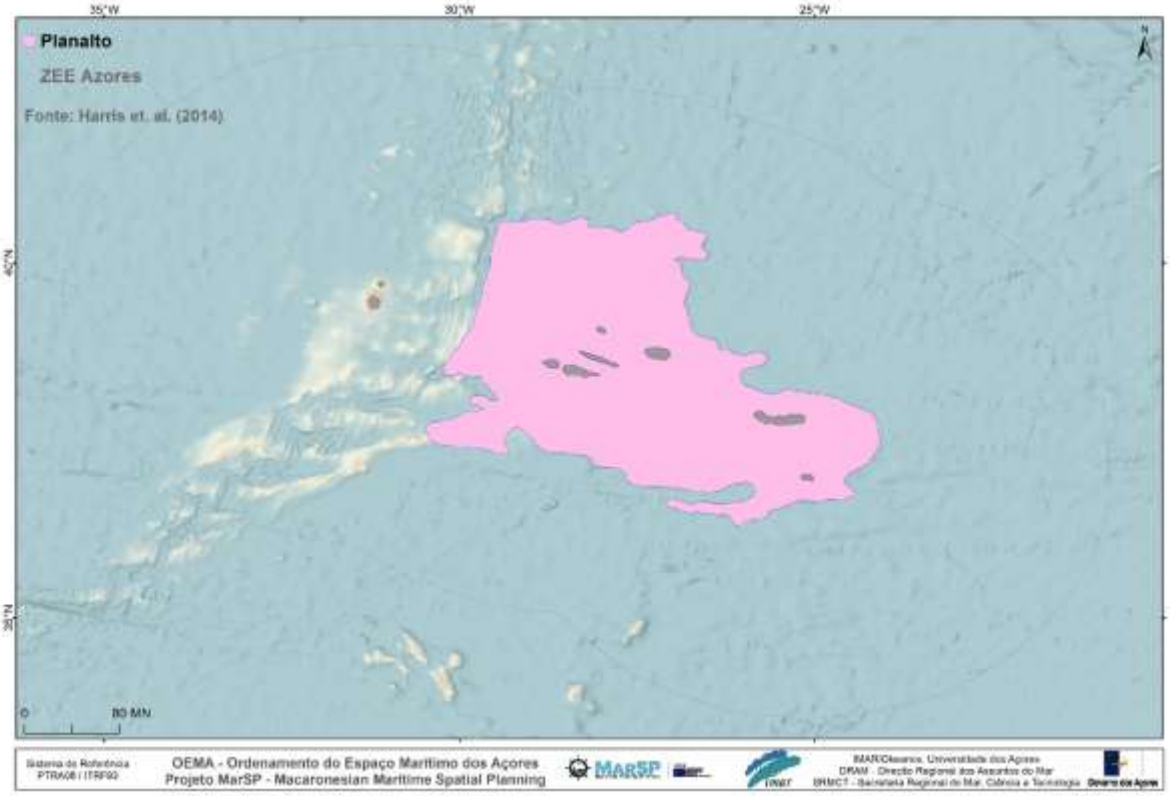
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, plateau, habitat

Summary: The plateau geomorphic feature layer represents the spatial extent of the plateaus of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Plateaus of the EEZ of the Azores



Description: The plateau geomorphic feature layer represents the spatial extent of the plateaus of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). Plateaus are "flat or nearly flat elevations of considerable areal extent, dropping off abruptly on one or more sides" (IHO, 2008). Plateaus were digitised by hand based on 100 m contours. In areas where plateaus abut the margin, the foot of slope was allowed to flow offshore to encompass the plateau feature, where a clear seaward dipping gradient was apparent. In other locations marginal plateaus are distinctly separate from the continental slope and form isolated, raised platforms. The geomorphic features map of Agapova et al (1979) and the GEBCO Gazetteer of geographic names of undersea features were used to ensure all named features were included.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris et. al. (2014) Geomorphology of the oceans. Marine Geology, 352 (4-24).

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Point of Contact:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
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High precision true
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1.4.6. Ridges

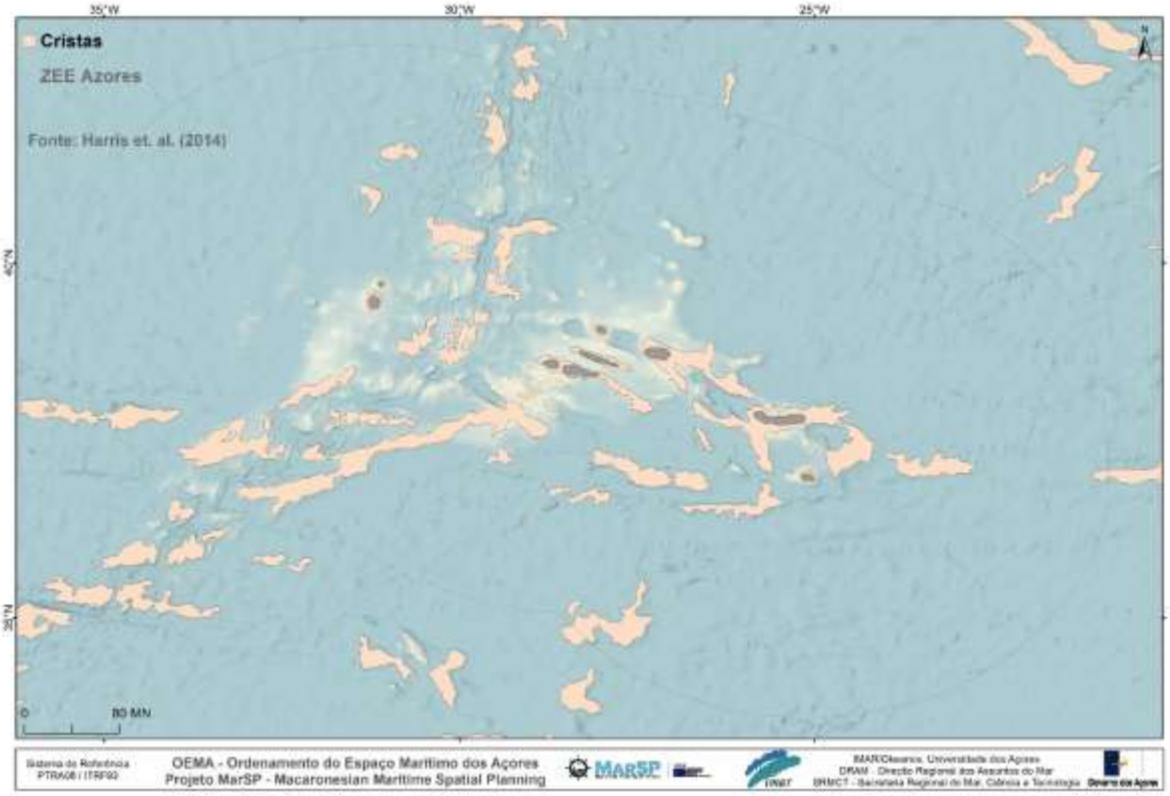
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, ridge, habitat

Summary: The ridge geomorphic feature layer represents the spatial extent of the ridges of the Azores, based on interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Ridges of the EEZ of the Azores



Description: The ridge geomorphic feature layer represents the spatial extent of the ridges of the Azores, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). Ridges in this study are confined to "an isolated (or group of) elongated narrow elevation(s) of varying complexity having steep sides, often separating basin features" (IHO 2008). In this study "ridges" were confined to features greater than 1,000 m in relief and do not include the mid-ocean ridges, which was mapped as a separate feature.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Point of Contact:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
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1.4.7. Rift valleys

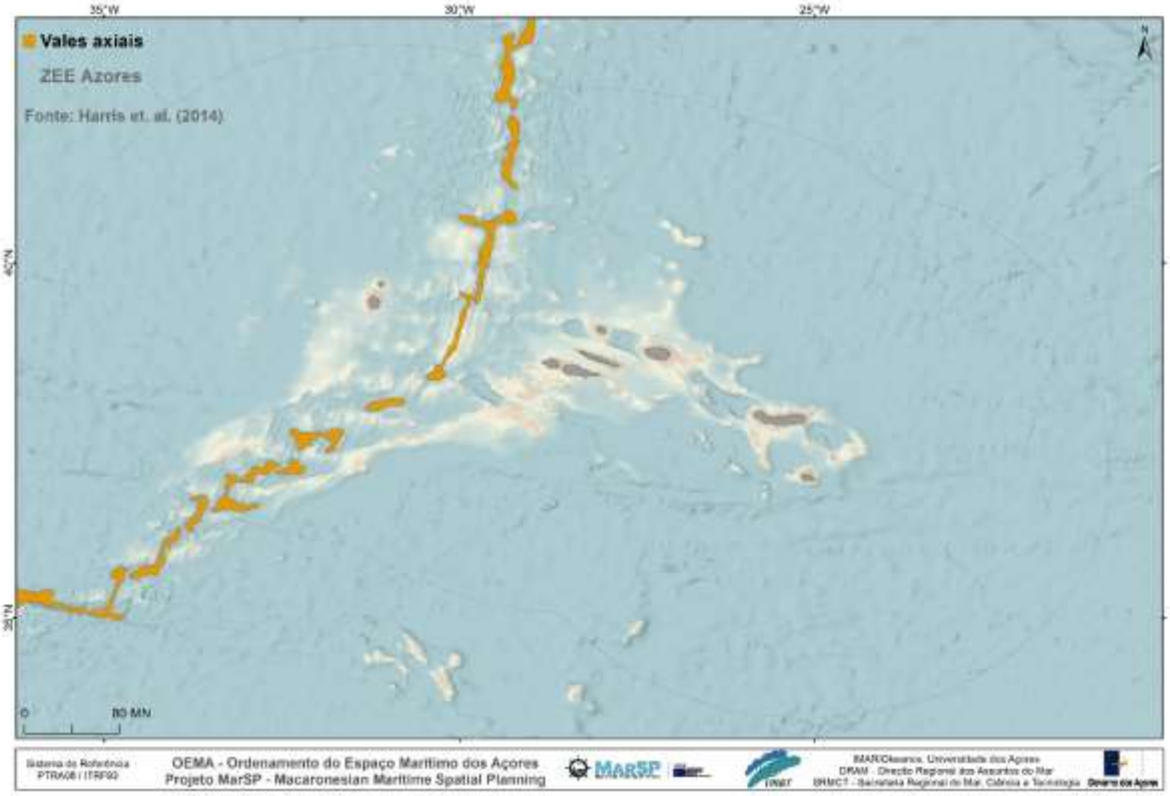
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, rift valley, habitat

Summary: The rift valley geomorphic feature layer represents the extent of the rift valleys of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Rift valleys of the EEZ of the Azores



Description: The rift valley geomorphic feature layer represents the spatial extent of the rift valleys of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). Rift valleys were mapped as separate features in the present study where they are clearly evident in SRTM30_PLUS bathymetric data. Rift valleys are confined to the central axis of mid-ocean spreading ridges; they are elongate, local depressions flanked generally on both sides by ridges (Macdonald, 2001). They were mapped by hand based on 100 m contours.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Point of Contact:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

1.4.8. Shelf classification

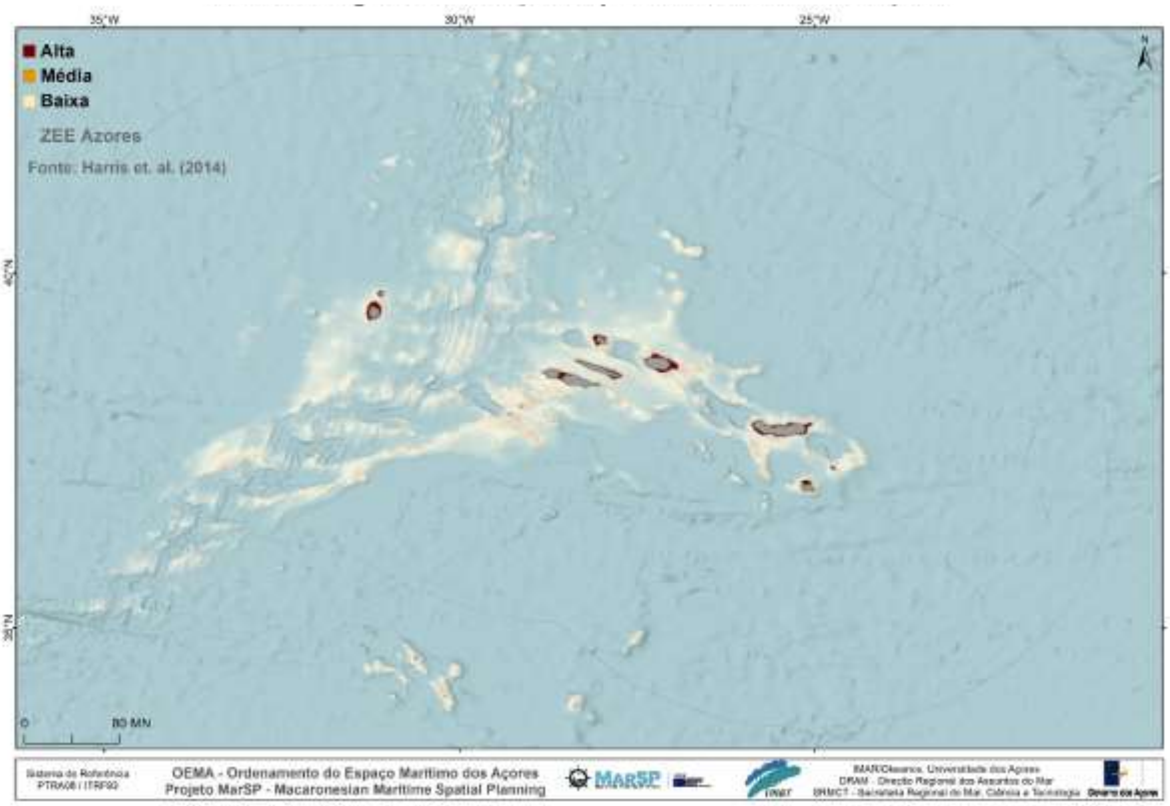
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, shelf classification, habitat

Summary: The shelf classification geomorphic feature layer represents the spatial extent of the low, medium and high profile shelf areas of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Shelf classification of the EEZ of the Azores



Description: The shelf classification geomorphic feature layer represents the spatial extent of the low, medium and high profile shelf areas of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). The continental shelf is defined by IHO (2008) as "a zone adjacent to a continent (or around an island) and extending from the low water line to a depth at which there is usually a marked increase of slope towards oceanic depths". The low-water mark is taken in this study as the 0 m depth contour. The shelf break (i.e. the line along which there is marked increase of slope at the seaward margin of a shelf) was digitised manually at a nominal spatial scale of 1:500,000 in ArcGIS based on 10 m, 50 m and 100 m contours, depending on the slope and bathymetric profile of the region. In most cases 100 m contours were sufficient at the selected scale of 1:500,000 to identify the shelf break. However, where there was a gradual break in slope over a broad area, more closely spaced contours were used. Floating ice shelves cover large sections of the Antarctic continental shelf and these areas were simply left blank. A classification of the continental shelf based on vertical relief yielded three classes: Low-relief shelf; Medium-relief shelf; and High-relief shelf. To generate these classes, the SRTM model was sub-classified based on the variation over a five-cell radius into areas of low (< 10m), medium (10-50 m) and high (>50 m) vertical relief.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West -30.478154 East -17.000000
North 40.713523 South 34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Point of Contact:
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ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
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Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

1.4.9. Slope

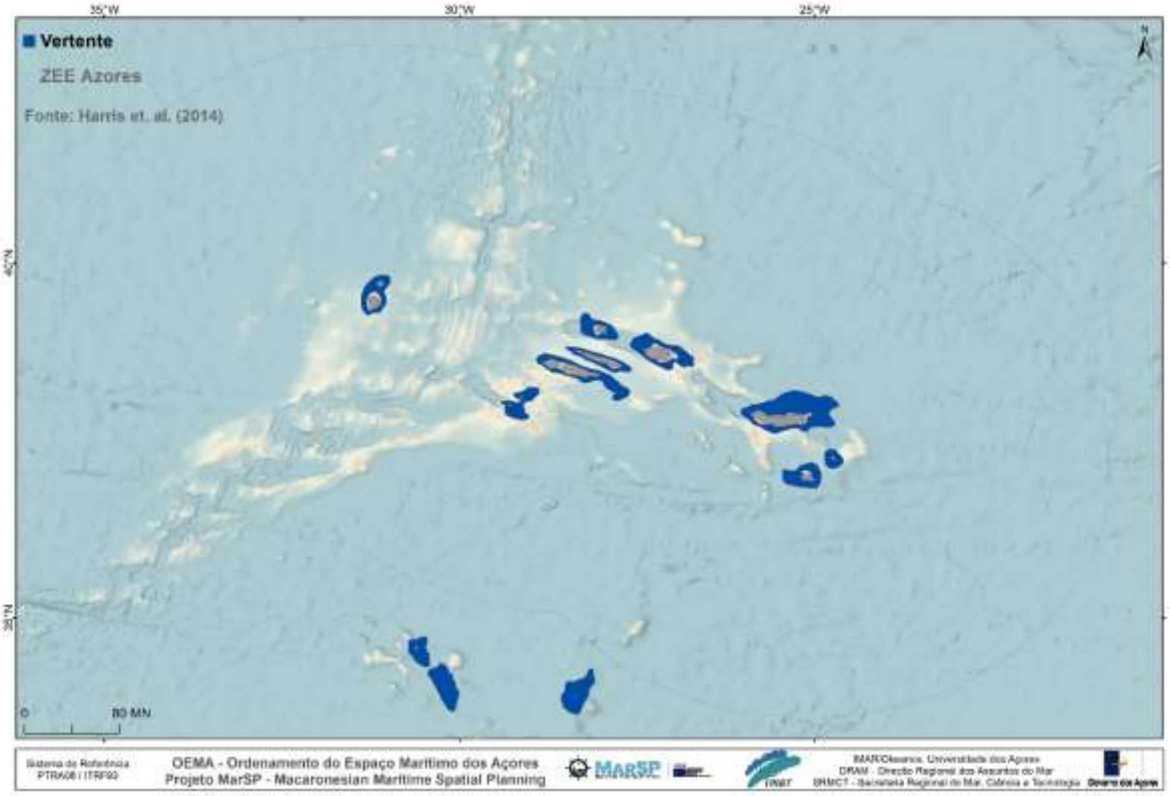
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, slope, habitat

Summary: The slope geomorphic feature layer represents the spatial extent of the slope areas of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Slopes of the EEZ of the Azores



Description: The slope geomorphic feature layer represents the spatial extend of the slope areas of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). The slope is "the deepening sea floor out from the shelf edge to the upper limit of the continental rise, or the point where there is a general decrease in steepness" (IHO, 2008). In this study, the foot of slope was digitised manually at a nominal spatial scale of 1:500,000 in ArcGIS based on 100 m contours and 3D viewing. ArcGIS was used to highlight zones of abrupt changes in seabed gradient (contour spacing) which suggests the foot of slope in many areas. In areas where marginal plateaus abut the margin, the foot of slope was allowed to extend offshore to encompass the plateau feature, where a clear seaward dipping gradient was apparent. Otherwise the first significant decrease in gradient encountered in a seaward direction from the shelf break was selected as the foot of slope. Note our foot of slope locations are based only on bathymetric data and our interpretation is not intended to define the foot of slope under Article 76 of the 1982 United Nations Convention on the Law of the Sea, particularly in areas of geomorphologically complex, continent-ocean transition.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Point of Contact:
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ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
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Y ORIGIN -400
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Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

1.4.10. Mid-Atlantic Ridges

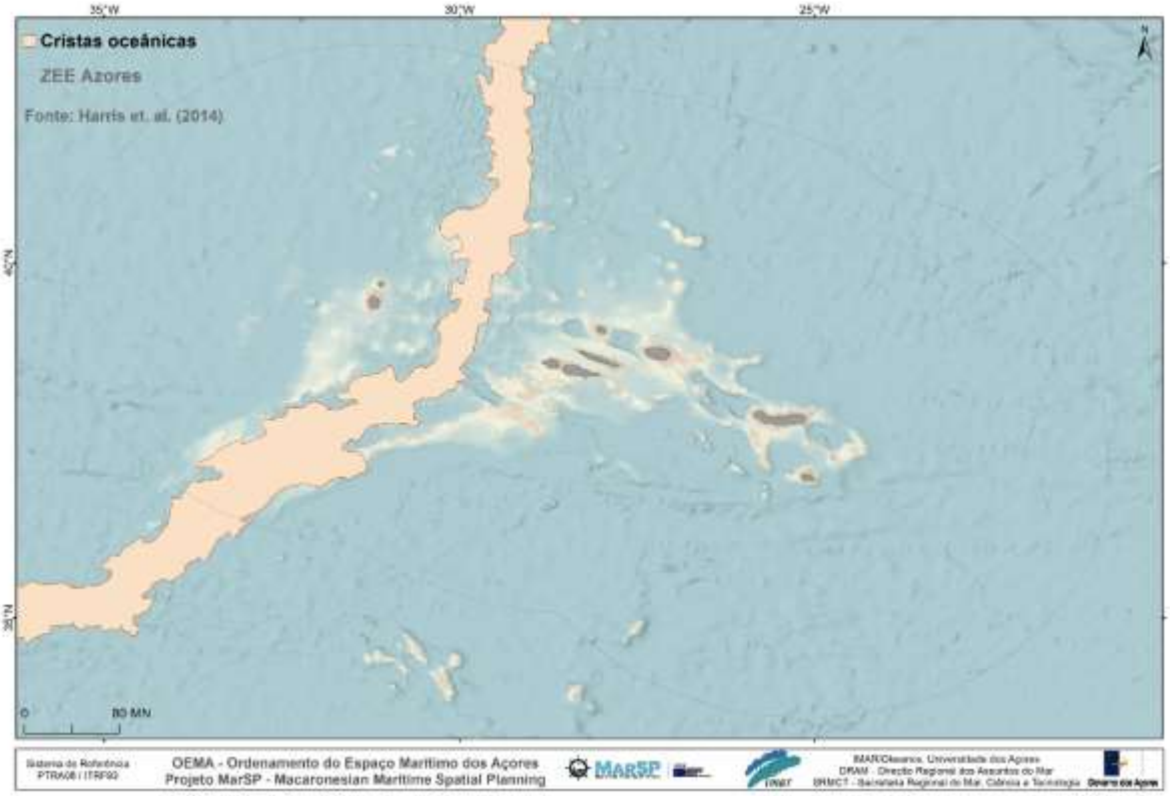
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, seafloor, geomorphology, geomorphic feature, spreading ridge, habitat

Summary: The spreading ridge geomorphic feature layer represents the spatial extent of the spreading ridges of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Mid-Atlantic Ridges of the EEZ of the Azores



Description: The spreading ridge geomorphic feature layer represents the spatial extent of the spreading ridges of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et.al. 2014). Mid-ocean spreading ridges are "the linked major mid-oceanic mountain systems of global extent" (IHO, 2008). Spreading ridges are distinguished from other ridges in this study (see definition of ridges below). They were mapped by hand based on their appearance as ridge-like features that coincide with the youngest ocean crust as mapped by Müller et al. (1997) in their "EarthByte" digital age grid of the ocean floor. Spreading ridges that were not visible in the SRTM30_PLUS bathymetry (100 m contours) were not included in our interpretation, but there is otherwise no size limitation on spreading ridges.

Credits: The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Reference: Harris, P., M. Macmillan-Lawler, J. Rupp, and E. Baker (2014). *Geomorphology of the oceans*. Marine Geology, v. 352, p. 4-24

Use Limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-30.478154	East	-17.000000
North	40.713523	South	34.260461

Citation Contacts:
INDIVIDUAL'S NAME Miles Macmillan-Lawler
ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
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Point of Contact:
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ORGANIZATION'S NAME GRID-Arendal
CONTACT'S ROLE custodian
E-MAIL ADDRESS: Miles.Macmillan-Lawler@grida.no

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

1.4.11. Troughs

Shapefile: Polygon (1: 1 000 000)

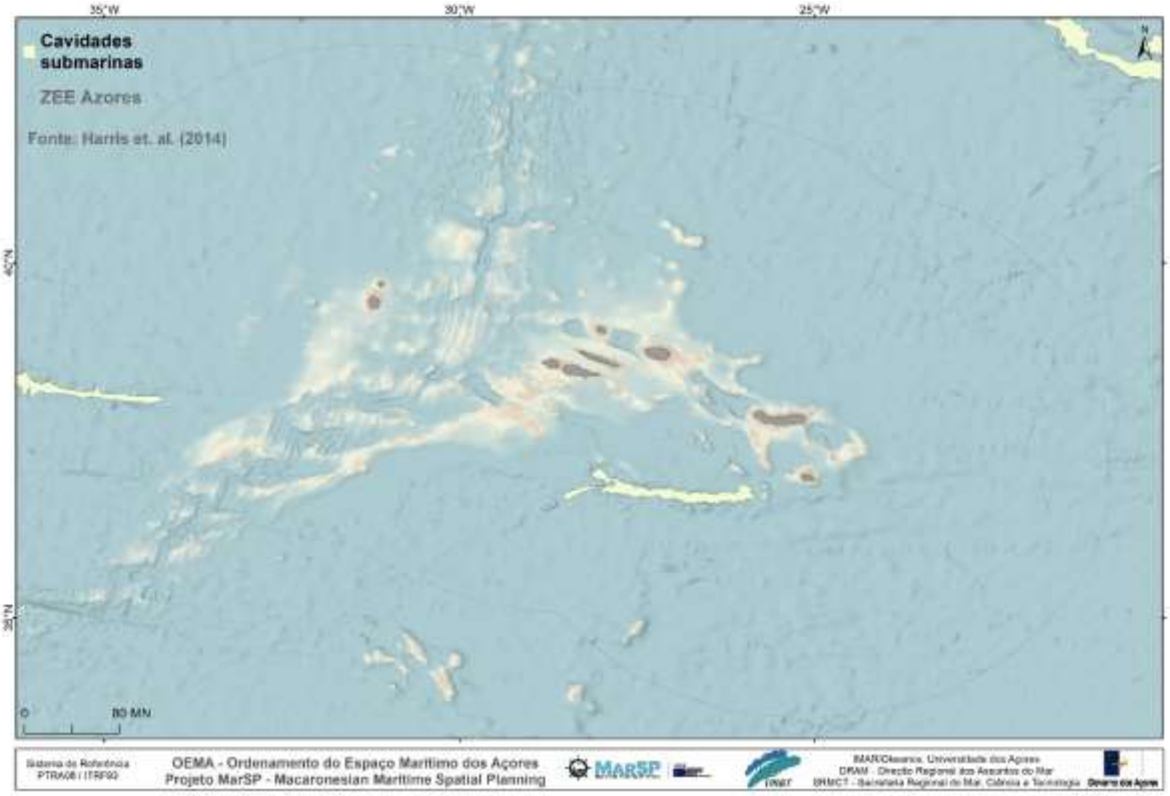
Year: 2014

Shapefile: Point (1:5 000 000)

Keywords: Azores, seafloor, geomorphology, geomorphic feature, trough, habitat.

Summary: The trough geomorphic feature layer represents the spatial extent of the troughs of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The global seafloor geomorphic features map is intended to support ocean management including feature inventories, spatial planning and biodiversity conservation.

Geomorphology: Troughs of the EEZ of the Azores



Description: The trough geomorphic feature layer represents the spatial extent of the troughs of the Azores region, based on interpretation of the SRTM30 plus v7 global bathymetry model. The layer is one of the 25 layers that make up the global seafloor geomorphic features map (Harris et al. 2014). The IHO (IHO, 2008) definition of a trough is "a long depression of the sea floor characteristically flat bottomed and steep sided and normally shallower than a trench". In this study we found that troughs are also commonly open at one end (i.e. not defined by closed bathymetric contours) and their broad, flat floors may exhibit a continuous gradient along a thalweg. Troughs maY ORIGINate from glacial erosion processes or have formed through tectonic processes. In this study, glacial troughs incised into the shelf are a separate category; here we include all troughs not of a glacial origin, typically superimposed on the slope and/or abyssal base layers. Trenches that have been infilled with sediment may evolve into troughs, as appears to have occurred in troughs adjacent to North and South America, for example. Slumping on the sides of some troughs has formed a bridge across the trough, thereby dividing it into two separate sections (see "bridges" below). In this study all troughs were digitised by hand based on the interpretation of 100 m bathymetric contours.

The global seafloor geomorphic features map has been produced through a collaboration between Geoscience Australia, GRID-Arendal and Conservation International.

Credits: IMAR/Okeanos. University of the Azores

Use limitations: The global seafloor geomorphic feature map is available for download from bluehabitats.org

Extent:

West	-39.250797	East	-19.224544
North	44.405465	South	36.591406

Citation Contacts:
ORGANIZATION'S NAME GRID-Arendal
INDIVIDUAL'S NAME Miles Macmillan-Lawler
CONTACT'S POSITION Custodian
E-MAIL ADDRESS Miles.Macmillan-Lawler@grida.no

Point of Contact:
INDIVIDUAL'S NAME Luís Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
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GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2. Inventory of Spatial Data Sets: Oceanography

The collection of topics about sea environment of the Azores includes very diverse information about oceanographical, physical and biological characteristics of the Region. Information about water masses, temperature, chlorophyll-a concentration, particulate organic matter and nutrients can be found here.

Topic	**Spatial Data Set**	**Spatial Data Type**	**Year (Last update)**
Ocean Environmental Variables	Particulate Inorganic Carbon	Raster	2014
	Particulate Organic Carbon	Raster	2014
	Chlorophyll-a Concentration	Raster	2014
	Ocean Productivity	Raster	2014
	Photosynthetically Available Radiation	Raster	2014
	Sea Surface Temperature	Raster	2014
Seabed Chemical & Physical Conditions	Bottom Alkalinity	Raster	2009
	Apparent Oxygen Utilization	Raster	2009
	Omega Aragonite Saturation in the Seabed	Raster	2009
	Omega Calcite Saturation in the Seabed	Raster	2009
	Dissolved Oxygen in the Seabed	Raster	2009
	Bottom Nitrate Concentration	Raster	2009
	Bottom Oxygen Saturation	Raster	2009
	Bottom pH	Raster	2009
	Bottom Phosphate Concentration	Raster	2009
	Bottom Salinity	Raster	2009
	Bottom Silicate Concentration	Raster	2009
	Bottom Current Intensity	Raster	2009
	Bottom Temperature	Raster	2009

Table 2. Spatial Data Sets of Oceanography.

2.1. Ocean Environmental Variables

Raster Dataset Series (6 Models)

These NASA global data have been obtained through the AQUA Nasa Mission. This mission is collecting about the Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. Launched in a sun-synchronous orbit on May 4, 2002 Aqua is second satellite in NASA's Earth Observing System (EOS) that is equipped with the Moderate Resolution Imaging Spectroradiometer (MODIS). (Source: http://podaac.jpl.nasa.gov/SeaSurfaceTemperature/AQUA)

It was necessary to process the global data, which were in HDF (HDF Standard Mapped Image File) format. It has been used different software to transform the data from HDF format to ESRI raster format: *HDFViewer, ConTEXT and Marine Geospatial Ecology Tools for ArcGIS.*

In this dataset, there are information about 6 ocean environmental variables:

- Particulate Inorganic Carbon;
- Particulate Organic Carbon;
- Chlorophyll-a concentration;
- Ocean Productivity;
- Photosynthetically Available Radiation;
- Sea Surface Temperature.

2.1.1. Particulate Inorganic Carbon (Interannual mean, 2002-2013)

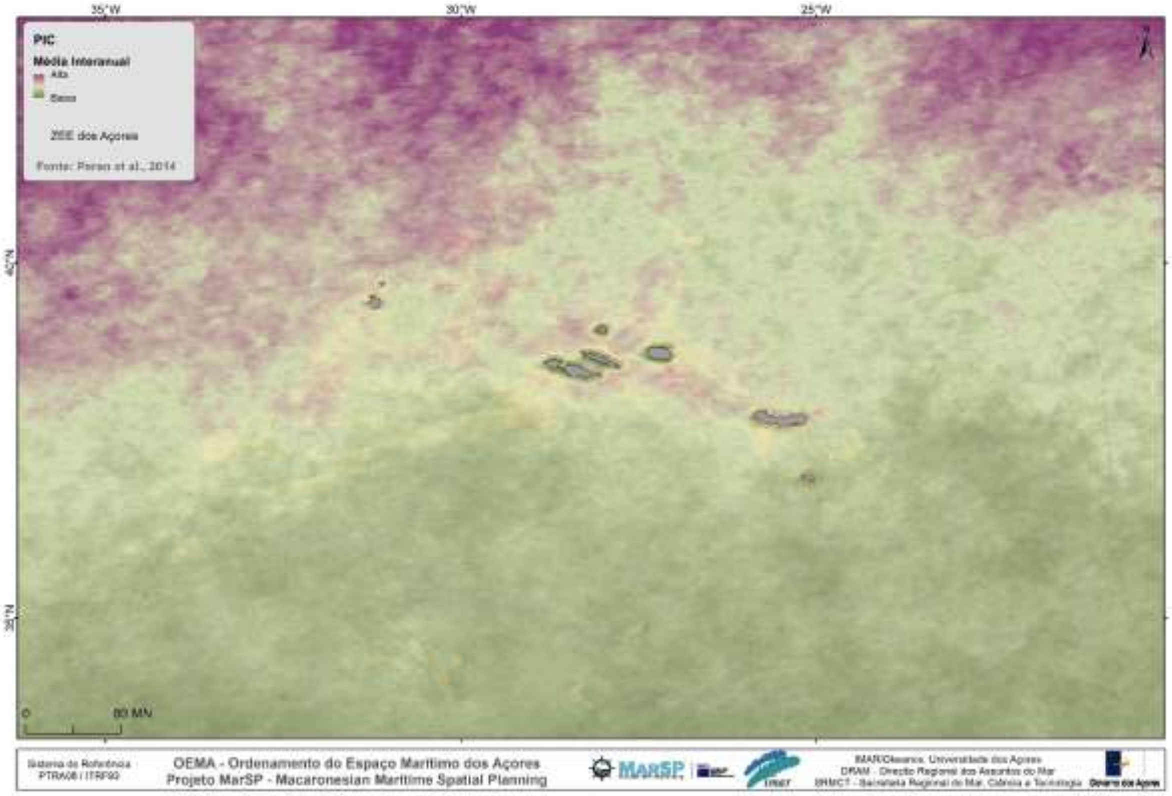
Raster Dataset: 4315.67m (368.86 KB)

Year: 2014

Keywords: Interannual, Azores, climatology, inorganic carbon, mean, ocean, parameter, satellite data, variable

Summary: This layer provides geographic information related to the interannual mean of the Particulate Inorganic Carbon in the Azores (North Atlantic Ocean) between the years 2002 and 2013. The units are mol/m^3.

Particulate Inorganic Carbon in the Azores (2002-2013)



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.234352 East -20.109351
North 43.451639 South 33.284972

Citation Contacts:
INDIVIDUAL'S NAME Antonio David Peran
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Biologist & GIS Technician
CONTACT'S ROLE Author

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
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Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
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GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2.1.2. Particulate Organic Carbon (Interannual mean, 2002-2013)

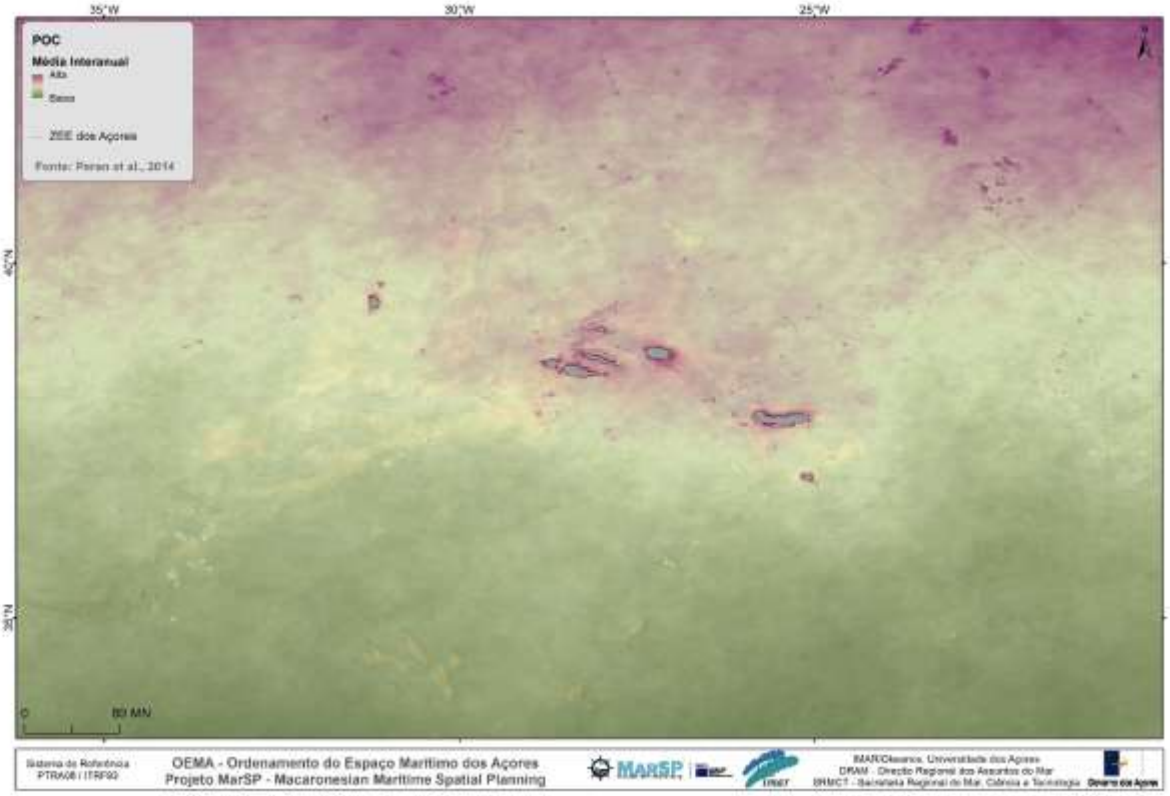
Raster Dataset: 4315.67m (368.86 KB)

Year: 2014

Keywords: Interannual, Azores, climatology, organic carbon, mean, ocean, parameter, satellite data, variable

Summary: This layer provides geographic information related to the interannual mean of the Particulate Inorganic Carbon in the Azores (North Atlantic Ocean) between the years 2002 and 2013. The units are ml/m^3.

Particulate Organic Carbon in the Azores (2002-2013)



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

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North	43.451639	South	33.284972

Citation Contacts:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
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Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

2.1.3. Chlorophyll-a Concentration (Interannual mean, 2002-2013)

Raster Dataset: 4315.67m (368.86 KB)

Year: 2014

Keywords: Interannual, Azores, climatology, Chlorophyll-a, mean, ocean, parameter, satellite data, variable

Summary: This layer provides geographic information related to the interannual mean of the Chlorophyll-a in the Azores (North Atlantic Ocean) between the years 2002 and 2013. The units are mg/m^3.

Chlorophyll-a Concentration in the Azores (2002-2013)

Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.234352 East -20.109351
North 43.451639 South 33.284972

Citation Contacts:
INDIVIDUAL'S NAME Antonio David Peran
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Biologist & GIS Technician
CONTACT'S ROLE Author

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
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* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
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Y ORIGIN -400
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M SCALE 10000
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Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
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GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2.1.4. Ocean Productivity (Interannual mean, 2002-2013)

Raster Dataset: 4315.67m (368.86 KB)

Year: 2014

Keywords: Interannual, Azores, climatology, Chlorophyll-a, mean, ocean, parameter, satellite data, variable

Summary: This layer provides geographic information related to the interannual mean of the ocean productivity in the Azores (North Atlantic Ocean) between the years 2002 and 2013. The units are mgC/m^2/day.

Ocean Productivity in the Azores (2002-2013)

Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.234352	East	-20.109351
North	43.451639	South	33.284972

Citation Contacts:
INDIVIDUAL'S NAME Antonio David Peran
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Biologist & GIS Technician
CONTACT'S ROLE Author

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

2.1.5. Photosynthetically Available Radiation (Interannual mean, 2002-2013)

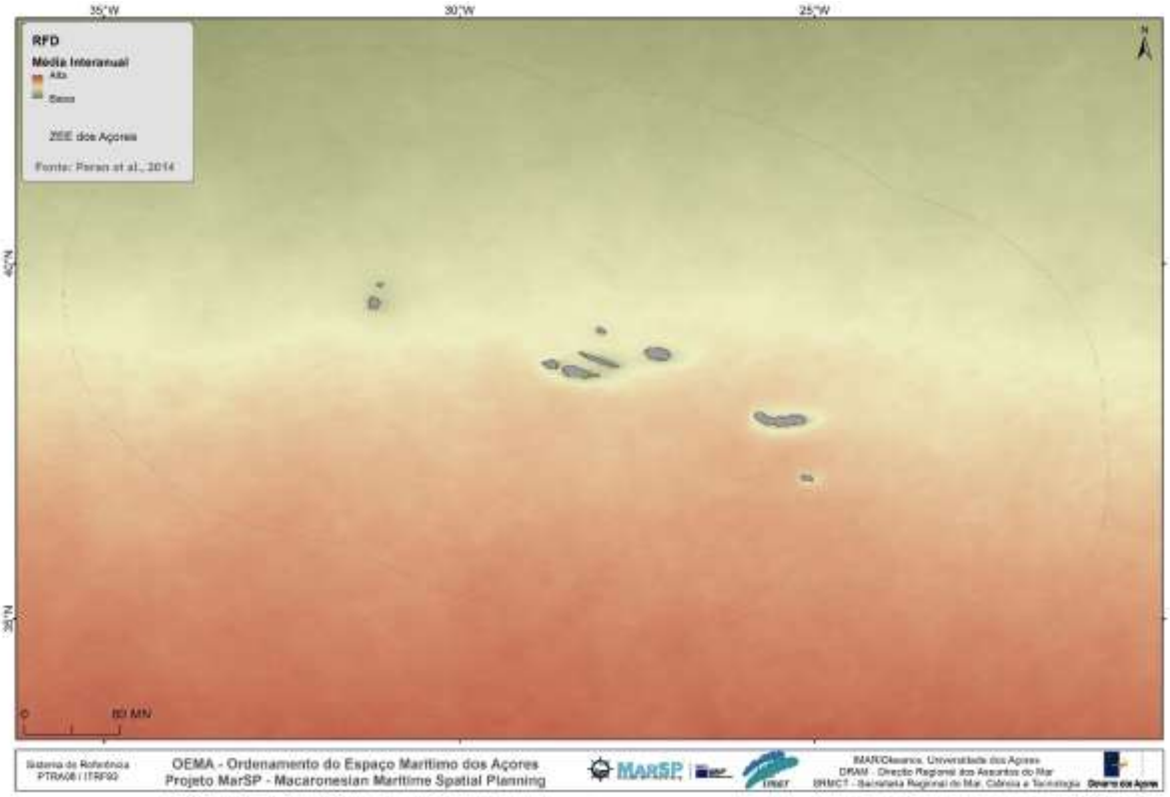
Raster Dataset: 4315.67m (368.86 KB)

Year: 2014

Keywords: Interannual, Azores, climatology, chlorophyll-a, mean, ocean, parameter, satellite data, variable

Summary: This layer provides geographic information related to the interannual mean of the Photosynthetically Available Radiation in the Azores (North Atlantic Ocean) between the years 2002 and 2013. The units are Einstein/m^2/day.

Photosynthetically Available Radiation in the Azores (2002-2013)



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.234352 East -20.109351
North 43.451639 South 33.284972

Citation Contacts:
INDIVIDUAL'S NAME Antonio David Peran
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Biologist & GIS Technician
CONTACT'S ROLE Author

Point of Contact:
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
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Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2.1.6. Sea Surface Temperature (Interannual mean, 2002-2013)

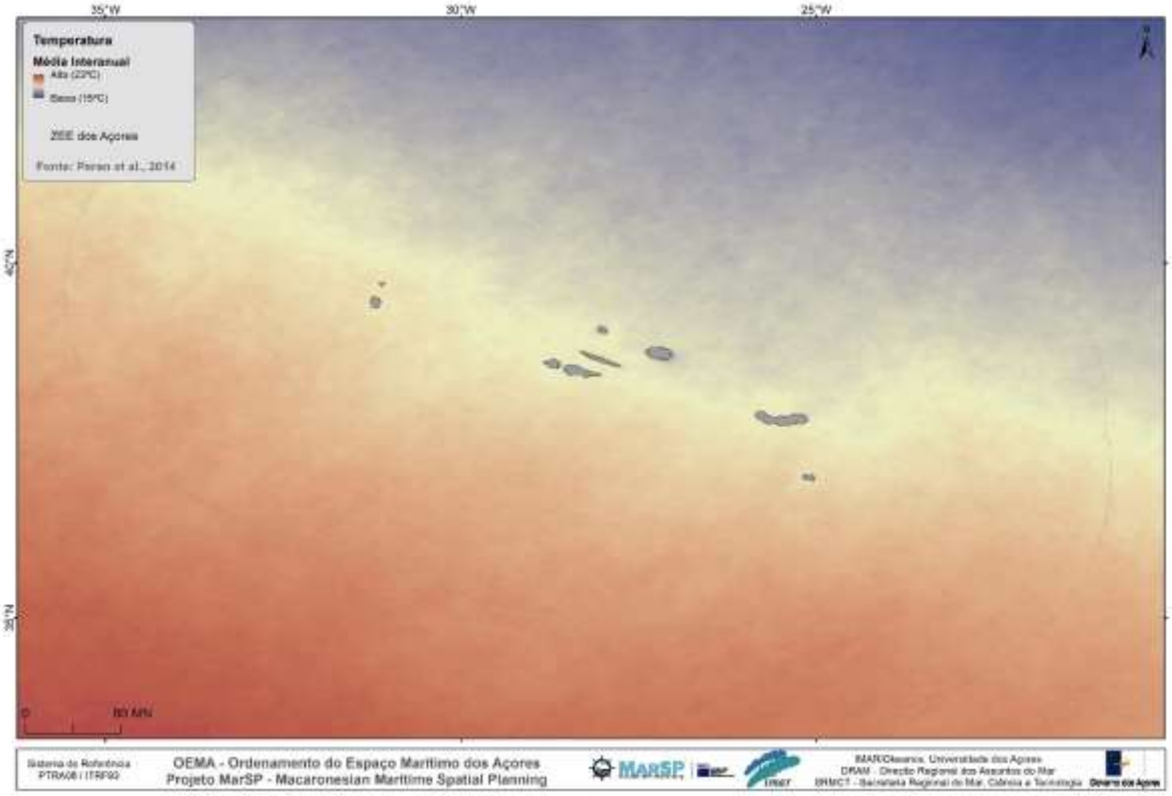
Raster Dataset: 4315.67m (368.86 KB)

Year: 2014

Keywords: Interannual, Azores, climatology, Chlorophyll-a, mean, ocean, parameter, satellite data, variable

Summary: This layer provides geographic information related to the interannual mean of the Sea Surface Temperature in the Azores (North Atlantic Ocean) between the years 2002 and 2013. The units are ºC.

Sea Surface Temperature in the Azores (2002-2013)



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.234352	East	-20.109351
North	43.451639	South	33.284972

Citation Contacts:

INDIVIDUAL'S NAME Antonio David Peran
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Biologist & GIS Technician
CONTACT'S ROLE Author

Point of Contact:

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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:

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* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

2.2. Seabed Chemical & Physical Conditions

Fernando Tempera and Chris Yesson, inside the CoralFish Project, have produced these 13 layers. The source to produce this layer was the Global Ocean Data Analysis Project (GLODAP).

The seabed chemical and physical conditions in the Azores, have been calculated by upscaling from the 280m resolution bathymetry. This technique involves resampling of neighbouring biogeochemical profiles and fried cells at the depth of the seabed cell. It produces continuous regional grids of oceanographic conditions near the seabed.

- CoralFish Project: CoralFISH is assessing the interaction between cold water corals, fish and fisheries, in order to develop monitoring and predictive modelling tools for ecosystem-based management in the deep water of Europe and beyond. (http://eu-fp7-coralfish.net/)
- GLODAP: The central objective of the Global Ocean Data Analysis Project (GLODAP) is to generate a unified data set to help determine the global distributions of both natural and anthropogenic inorganic carbon, including radiocarbon. These estimates provide an important benchmark against which future observational studies will be compared. (http://cdiac.ornl.gov/oceans/glodap/)

In this dataset, there are information about seabed chemical and physical conditions of the 13 topics:

- Bottom alkalinity;
- Apparent oxygen utilization;
- Omega aragonite saturation in the seabed;
- Omega calcite saturation in the seabed;
- Dissolved oxygen in the seabed;
- Bottom nitrate concentration;
- Bottom oxygen saturation;
- Bottom pH;
- Bottom phosphate concentration;
- Bottom salinity;
- Bottom silicate concentration;
- Bottom current intensity;
- Bottom temperature.

2.2.1. Bottom Alkalinity

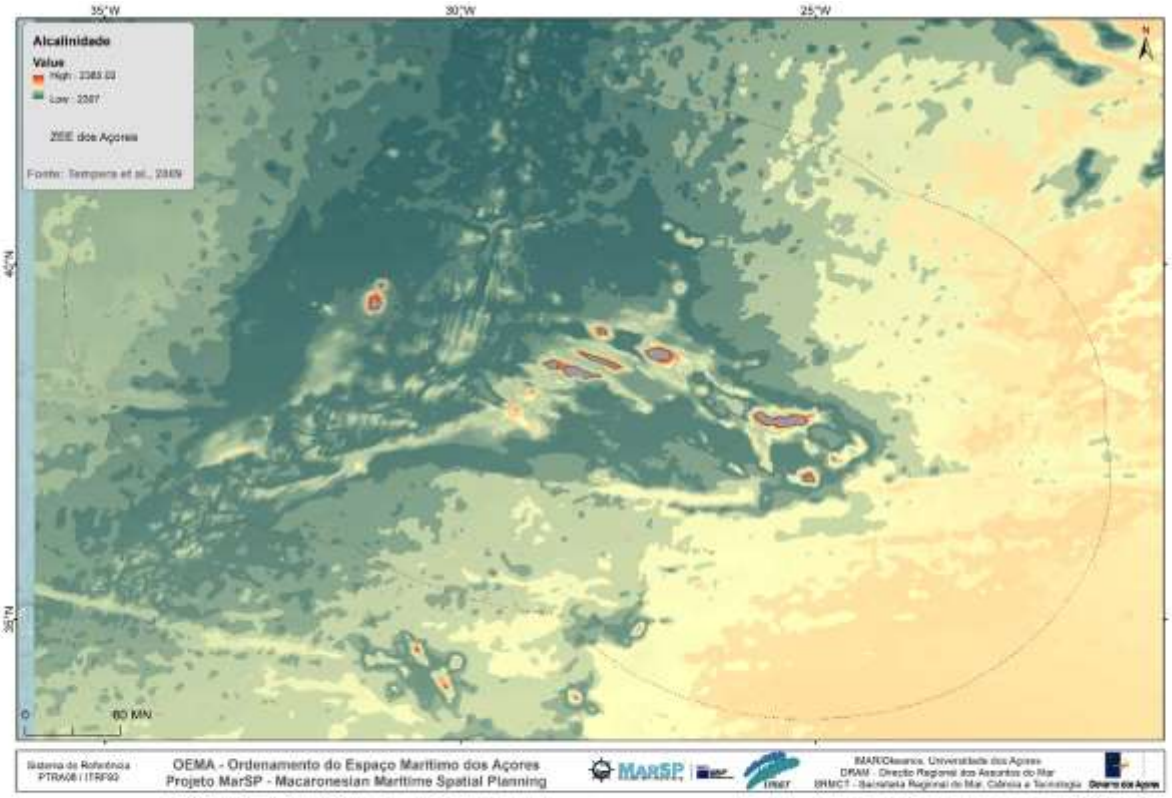
Raster Dataset: 279.507m (1150KB)

Year: 2009

Keywords: Azores, bottom alkalinity, chemical conditions, GLODAP, seabed

Summary: This layer provides geographic information related to the bottom alkalinity in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry.

Bottom alkalinity in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
CONTACT'S ROLE Author
E-MAIL ADDRESS ftempera@hotmail.com

Point of contact:
INDIVIDUAL'S NAME Luis Rodrigues
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
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Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2.2.2. Apparent Oxygen Utilization

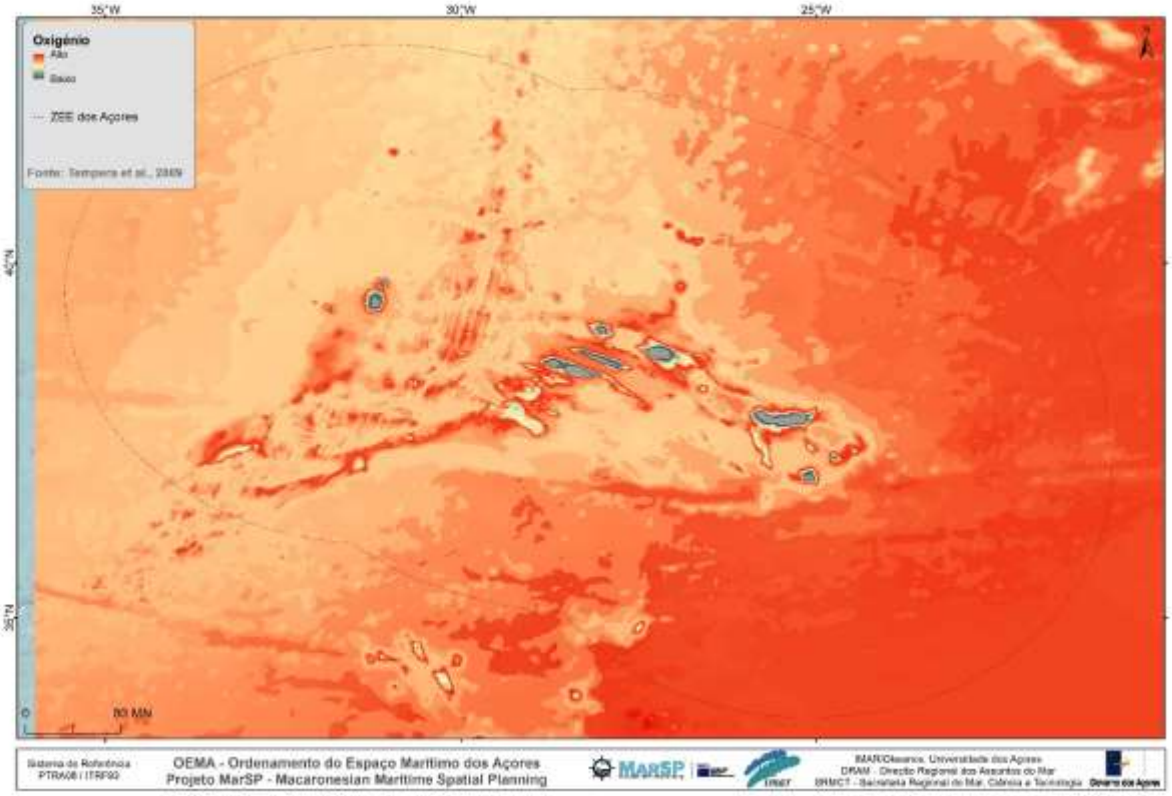
Raster Dataset: 279.507m (1150KB)

Year: 2009

Keywords: Azores, chemical conditions, oxygen utilization, seabed

Summary: This layer provides geographic information related to the bottom apparent oxygen utilization in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry. The units are ml/l.

Apparent Oxygen Utilization in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

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Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
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ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
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Point of contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
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Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326

X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000

M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

High precision true
Left longitude -180
Latest well-known identifier 4326

2.2.3. Omega Aragonite Saturation in the Seabed

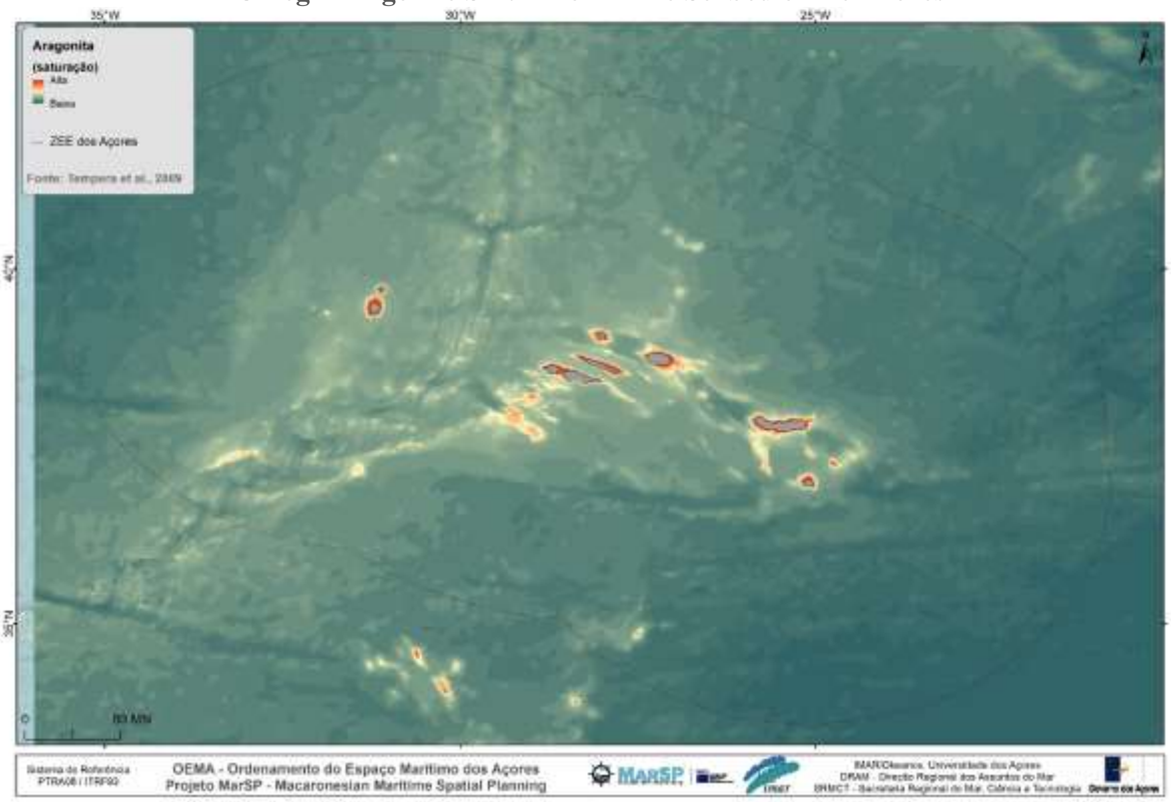
Raster Dataset: 279.507m (1150KB)

Year: 2009

Keywords: Azores, chemical conditions, omega aragonite, saturation, seabed

Summary: This layer provides geographic information related to the omega aragonite saturation in the seabed of the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry.

Omega Aragonite Saturation in the Seabed of the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
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Point of contact:
INDIVIDUAL'S NAME Luis Rodrigues
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
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Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
WELL-KNOWN TEXT GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]
Z SCALE 10000
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M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326

2.2.4. Omega Calcite Saturation in the Seabed

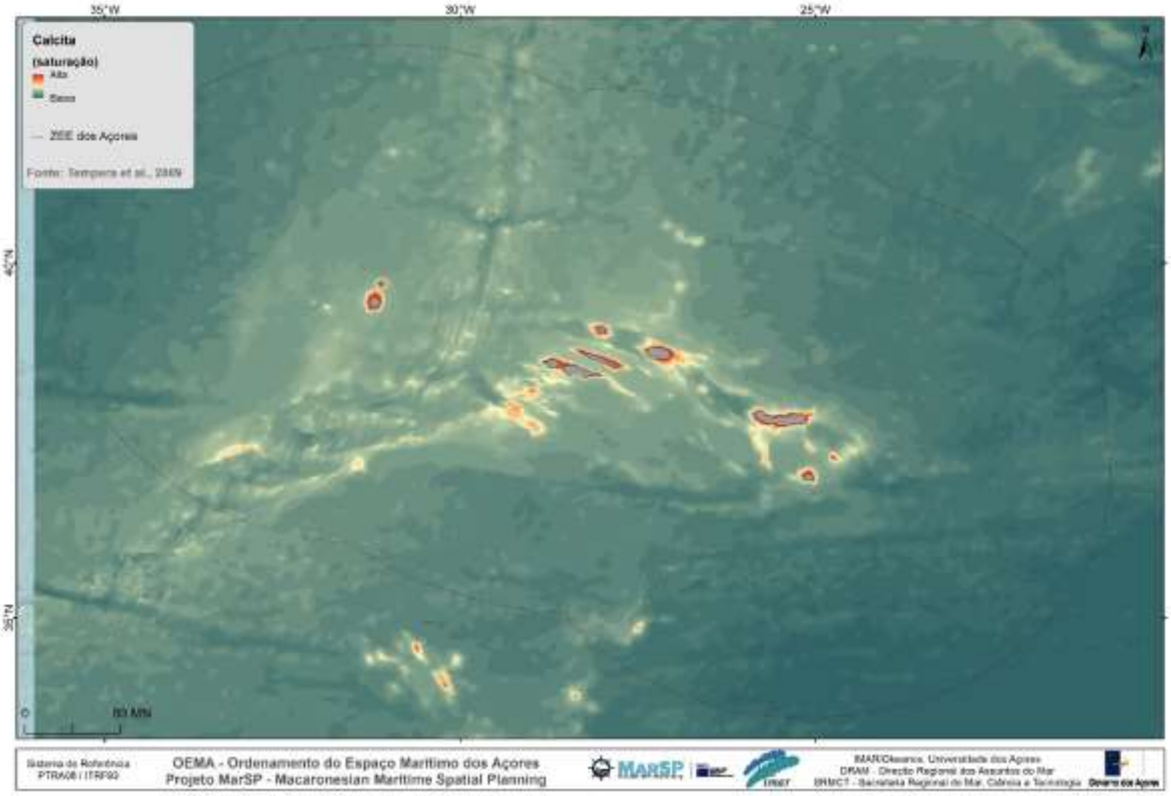
Raster Dataset: 279.507m (1150KB)

Year: 2009

Keywords: Azores, chemical conditions, omega calcite, saturation, seabed

Summary: This layer provides geographic information related to the omega calcite saturation in the seabed of the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry.

Omega Calcite Saturation in the Seabed of the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
CONTACT'S ROLE Author
E-MAIL ADDRESS ftempera@hotmail.com

Point of contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326

X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000

M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
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GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

High precision true
Left longitude -180
Latest well-known identifier 4326

2.2.5. Dissolved Oxygen in the Seabed

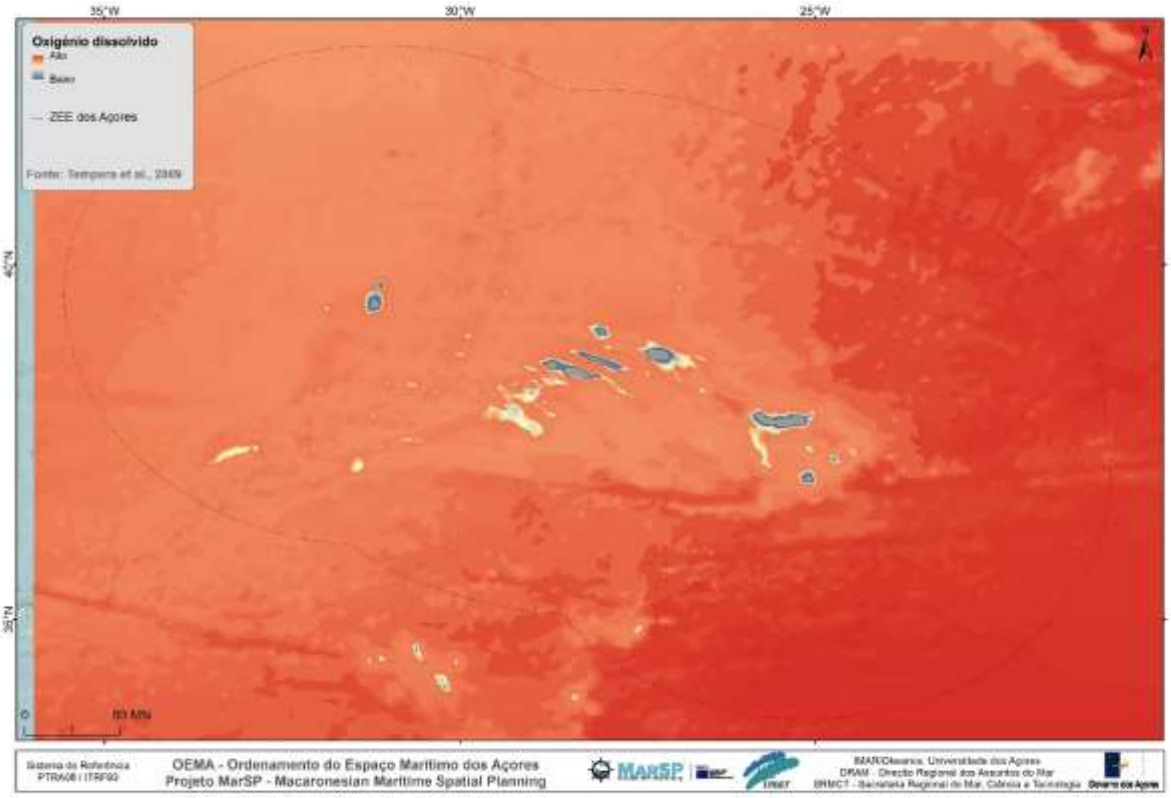
Raster Dataset: 279.507m (90KB)

Year: 2009

Keywords: Azores, chemical conditions, oxygen, saturation, seabed

Summary: This layer provides geographic information related to the dissolved oxygen in the seabed of the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry. The units are ml/l.

Dissolved Oxygen in the Seabed of the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.004142 East -19.998542
North 43.999767 South 32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
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Point of contact:
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
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Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2.2.6. Bottom Nitrate Concentration

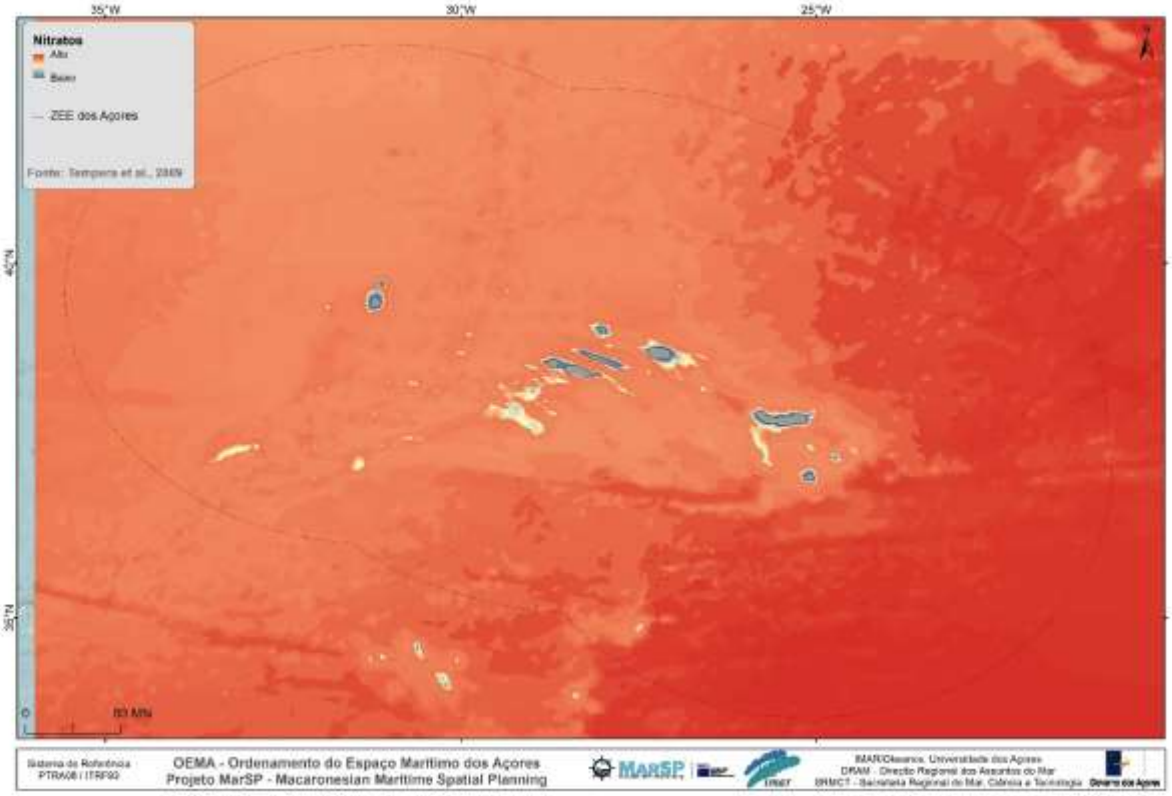
Raster Dataset: 279.507m (90KB)

Year: 2009

Keywords: Azores, bottom nitrate, chemical conditions, concentration, seabed, WOA 09

Summary: This layer provides geographic information related to the bottom nitrate concentration in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry. The units are µmol/l.

Bottom Nitrate Concentration in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
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ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
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Point of contact:
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326

X ORIGIN -400
Y ORIGIN -400
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Z SCALE 10000
M ORIGIN -100000

M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

High precision true
Left longitude -180
Latest well-known identifier 4326

2.2.7. Bottom Oxygen Saturation

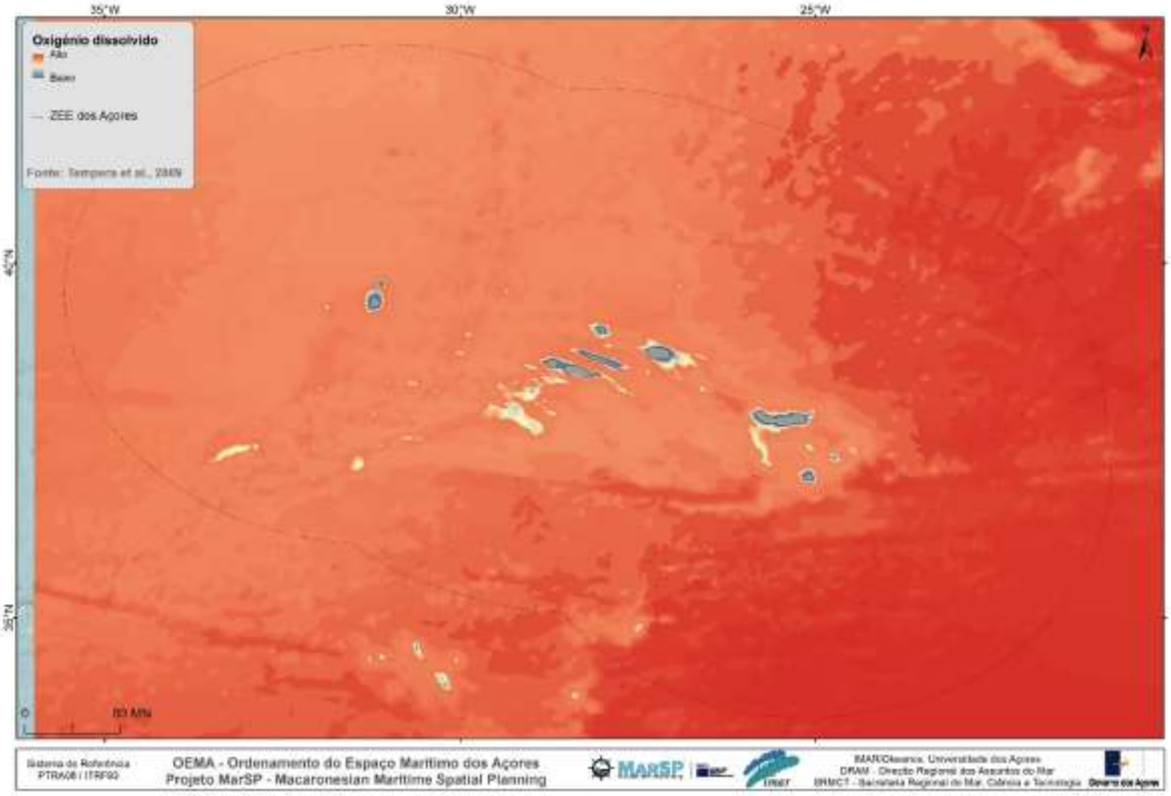
Raster Dataset: 279.507m (1150KB)

Year: 2009

Keywords: Azores, chemical conditions, oxygen saturation, seabed

Summary: This layer provides geographic information related to the bottom oxygen saturation in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry.

Bottom Oxygen Saturation in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
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E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
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Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2.2.8. Bottom pH

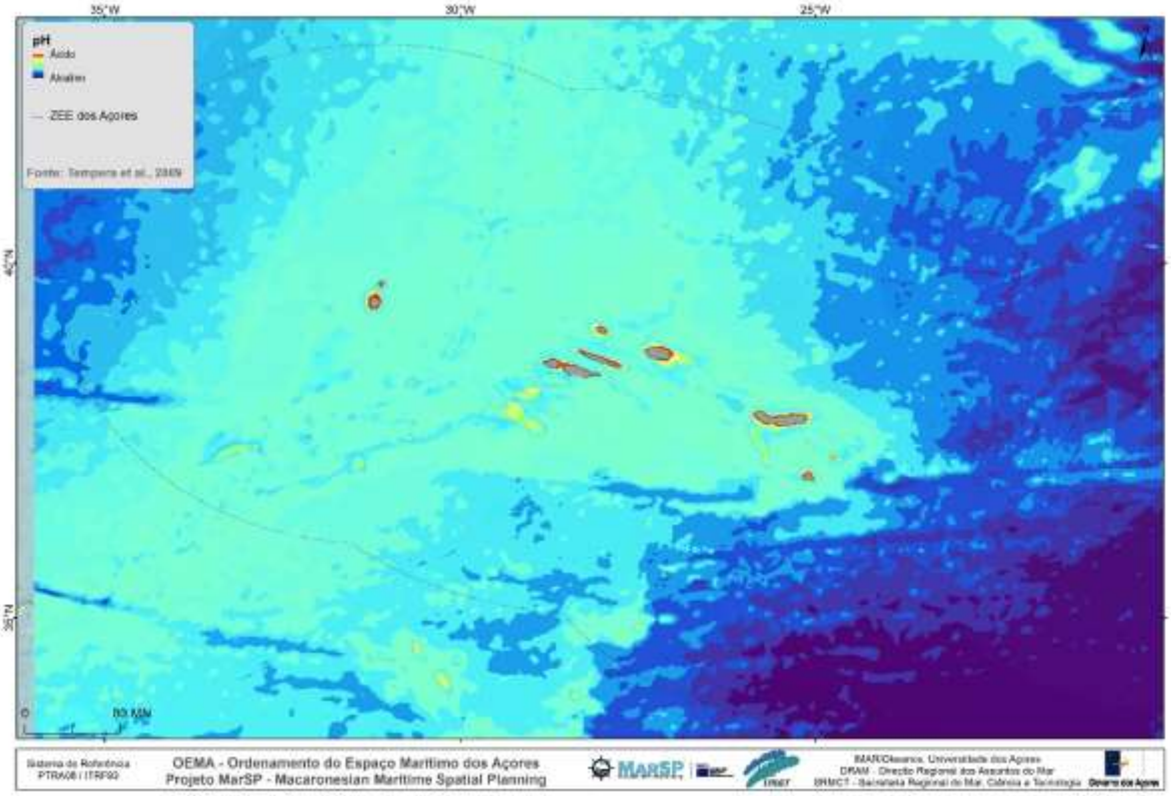
Raster Dataset: 427m (3KB)

Year: 2009

Keywords: Azores, chemical conditions, pH, seabed

Summary: This layer provides geographic information related to the bottom pH in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry.

Bottom pH in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
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Point of contact:
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326

X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000

M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

High precision true
Left longitude -180
Latest well-known identifier 4326

2.2.9. Bottom Phosphate Concentration

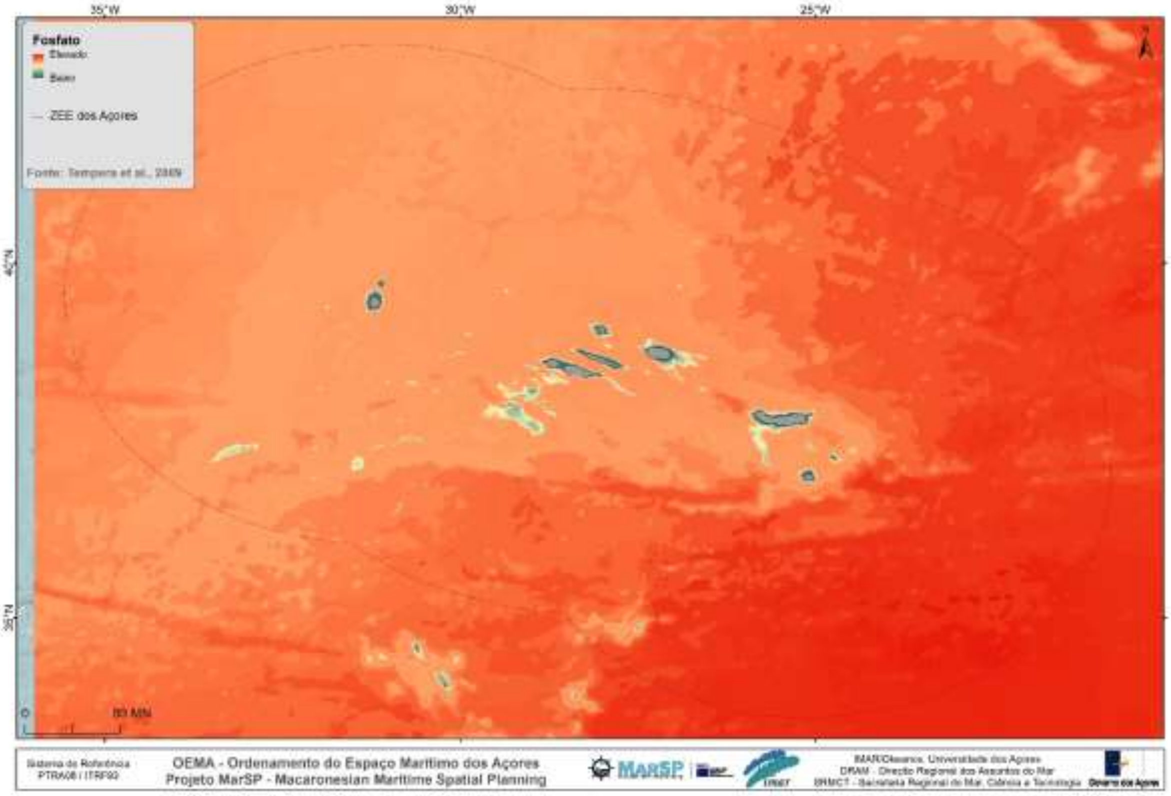
Raster Dataset: 279.507m (90KB)

Year: 2009

Keywords: Azores, chemical conditions, phosphate, seabed

Summary: This layer provides geographic information related to the bottom phosphate concentration in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry. The units are µmol/l.

Bottom Phosphate Concentration in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
CONTACT'S ROLE Author
E-MAIL ADDRESS ftempera@hotmail.com

Point of contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2.2.10. Bottom Salinity

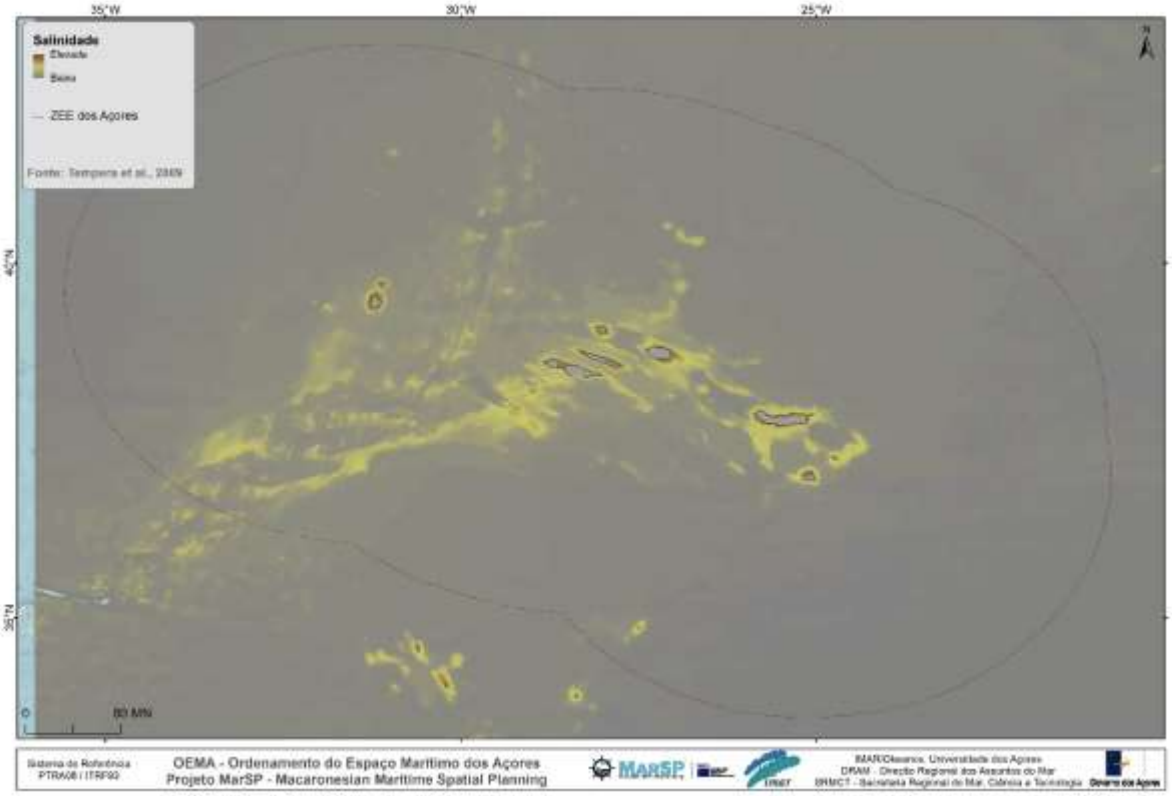
Raster Dataset: 279.507m (90KB)

Year: 2009

Keywords: Azores, chemical conditions, salinity, seabed

Summary: This layer provides geographic information related to the bottom salinity in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry.

Bottom Salinity in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

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North 43.999767 South 32.999967

Citation Contacts:

INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
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E-MAIL ADDRESS ftempera@hotmail.com

Point of contact:

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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:

* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326

X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000

M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

High precision true
Left longitude -180
Latest well-known identifier 4326

2.2.11. Bottom Silicate Concentration

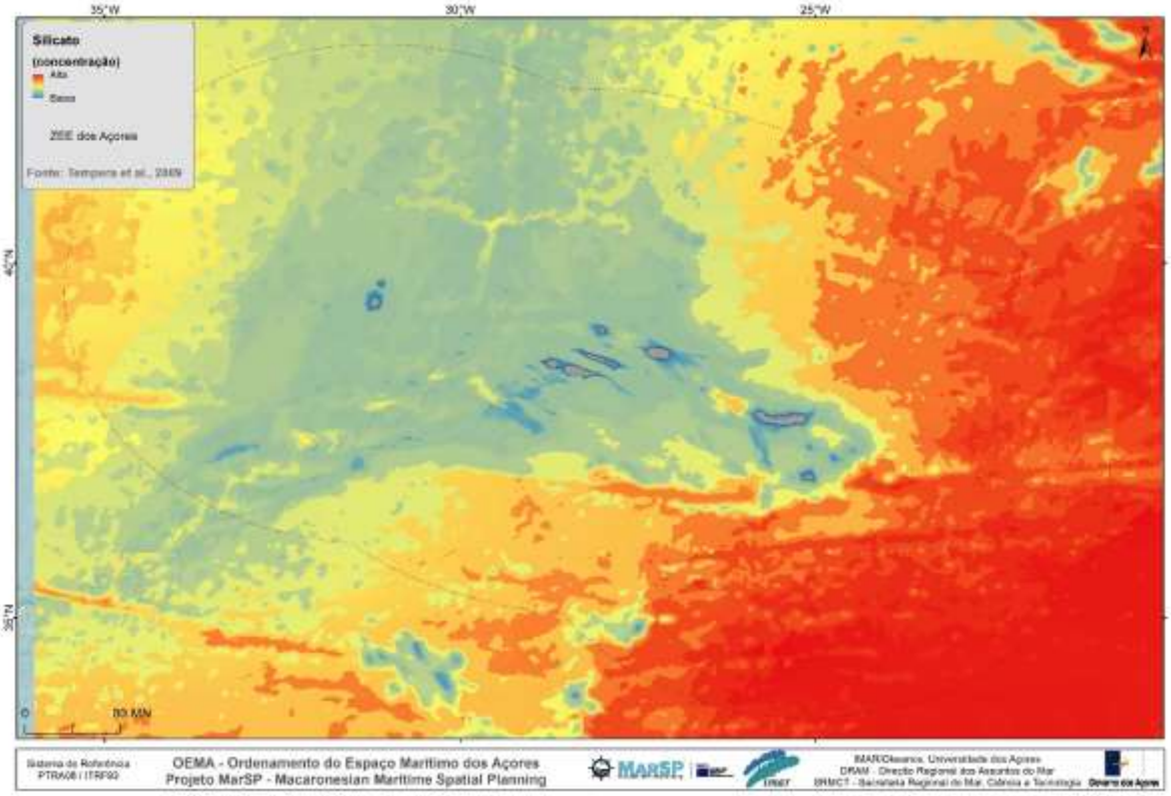
Raster Dataset: 279.507m (90KB)

Year: 2009

Keywords: Azores, chemical conditions, silicate concentration, seabed

Summary: This layer provides geographic information related to the bottom silicate concentration in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry. The units are µmol/l.

Bottom Silicate Concentration in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

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Extent:

West	-36.004142	East	-19.998542
North	43.999767	South	32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
CONTACT'S ROLE Author
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Point of contact:
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

2.2.12. Bottom Current Intensity

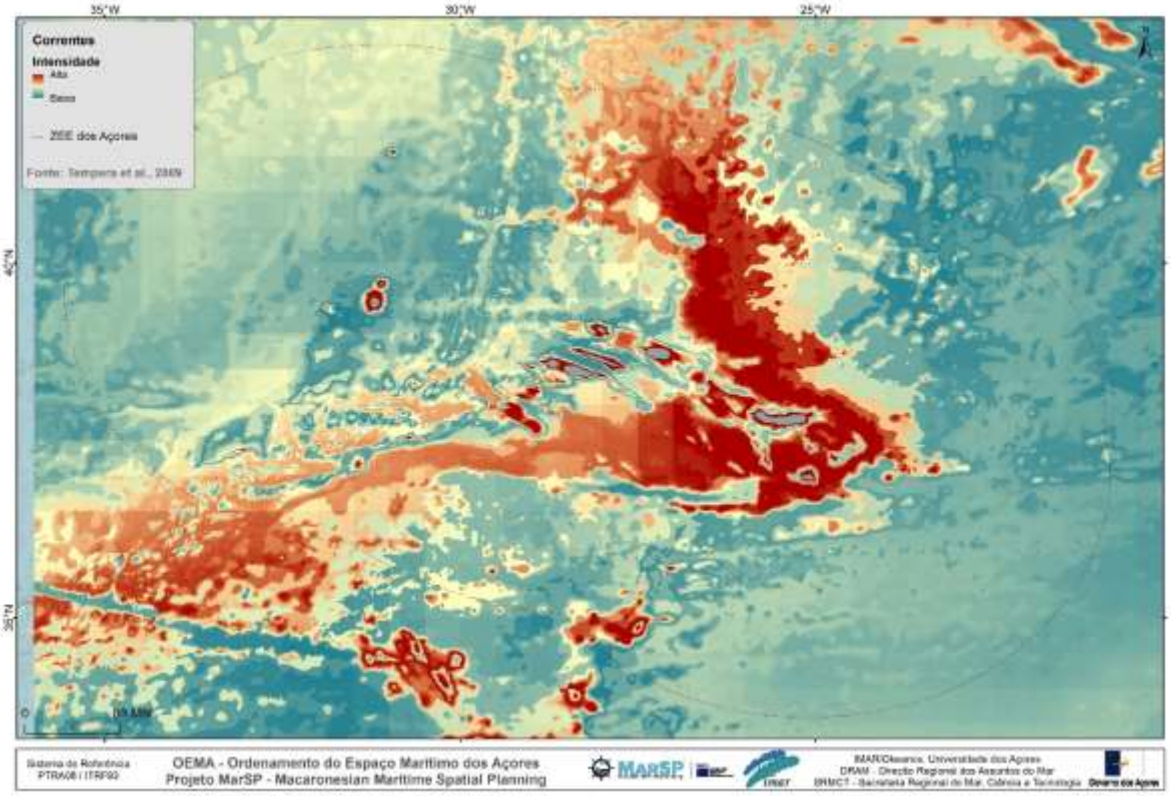
Raster Dataset: 279.507m (1150KB)

Year: 2009

Keywords: Azores, bottom, current intensity, ocean, seabed

Summary: This layer provides geographic information related to the bottom current intensity in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry.

Bottom Current Intensity in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

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North	43.999767	South	32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
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E-MAIL ADDRESS ftempera@hotmail.com

Point of contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326

X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000

M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

High precision true
Left longitude -180
Latest well-known identifier 4326

2.2.13. Bottom Temperature

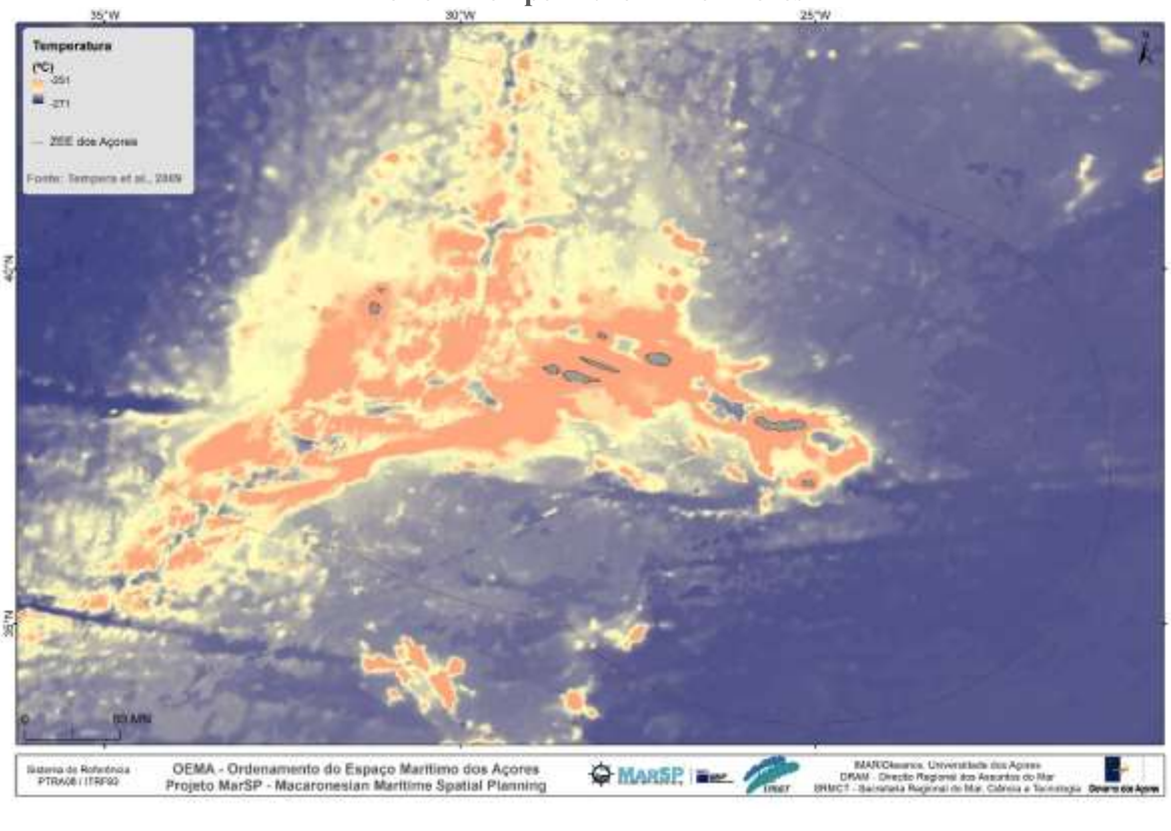
Raster Dataset: 863m (10KB)

Year: 2009

Keywords: Azores, bottom temperature, ocean, seabed

Summary: This layer provides geographic information related to the bottom temperature in the Azores. It has been calculated by upscaling from the 280 meters resolution bathymetry. The units are ºC.

Bottom Temperature in the Azores



Credits: CoralFish Project; IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores

Use limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.004142 East -19.998542
North 43.999767 South 32.999967

Citation Contacts:
INDIVIDUAL'S NAME Fernando Tempera
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Marine Biologist Researcher
CONTACT'S ROLE Author
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Point of contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
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E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3. Inventory of Spatial Data Sets: Biodiversity

The collection of topics about marine biodiversity of the Azorean sea includes very diverse information about several species, taxonomic groups, habitats or ecosystems. Information about spatial distribution of, for example, cetaceans, fishes, deep-sea sharks, birds and cold-water corals can be found here. Part of this information about habitats is available in point 1 of thispoint (Geomorphology/Bathymetry), specifically hydrothermal vents and seamounts.

Topic	**Spatial Data Set**	**Spatial Data Type**	**Year (last update)**
Cetaceans/ Whales	*Balaenoptera acutorostrata*, April-September	6xRaster	2014
	Balaenoptera borealis, April-September	6xRaster	2014
	Balaenoptera physalus, April-September	6xRaster	2014
	Balaenoptera musculus, April-September	6xRaster	2014
Cetaceans/ Sperm whales and beaked whales	*Physeter macrocephalus*, April-September	6xRaster	2014
	Ziphius cavirostris, April-September	6xRaster	2014
	Hyperoodon ampullatus, April-September	6xRaster	2014
	Mesoplodon spp., April-September	6xRaster	2014
Cetaceans/ Small dolphins	*Tursiops truncatus*, April-September	6xRaster	2014
	Stenella frontalis, April-September	6xRaster	2014
	Stenella coeruleoalba, April-September	6xRaster	2014
	Delphinus delphis, April-September	6xRaster	2014
Cetaceans/ Big dolphins	*Orcinus orca*, April-September	6xRaster	2014
	Grampus griseus, April-September	6xRaster	2014
	Pseudorca crassidens, April-September	6xRaster	2014
	Globicephala macrorhynchus, April-September	6xRaster	2014
Cold-water corals	*Acanella arbuscula*	Raster	2019
	Acanthogorgia spp.	Raster	2019
	Callogorgia verticillata	Raster	2019
	Coralliidae	Raster	2019
	Dentomuricea aff. *meteor*	Raster	2019
	Errina dabneyi	Raster	2019
	Leiopathes sp.	Raster	2019
	Lophelia pertusa	Raster	2019
	Madrepora oculata	Raster	2019
	Narella bellissima	Raster	2019
	Narella versluysi	Raster	2019
	Paracalyptrophora josephinae	Raster	2019
	Paragorgia johnsoni	Raster	2019
	Solenosmilia variabilis	Raster	2019
	Viminella flagellum	Raster	2019
Deep-water Sharks	*Centrophorus squamosus*	Raster	2019
	Centroscymnus coelolepis	Raster	2019
	Centroscymnus owstonii	Raster	2019
	Centroselachus crepidater	Raster	2019
	Dalatias licha	Raster	2019
	Deania calcea	Raster	2019
	Deania profundorum	Raster	2019
	Dipturus batis	Raster	2019
	Etmopterus princeps	Raster	2019
	Etmopterus pusillus	Raster	2019
	Etmopterus spinax	Raster	2019
	Galeorhinus galeus	Raster	2019
	Leucoraja fullonica	Raster	2019

	Raja clavata	Raster	2019
	Squaliolus laticaudus	Raster	2019
Fish Species Predictive Distribution Modelling	*Phycis phycis*/Forkbeard	Raster	2014
	Beryx splendens/Splendid alfonsino	Raster	2014
	Pontinus kuhlii/Offshore rockfish	Raster	2014
	Helicolenus dactylopterus/Blackbelly rosefish	Raster	2014
	Polyprion americanus/Wreckfish	Raster	2014
	Pagellus bogaraveo/Red sea bream	Raster	2014
	Beryx decadactylus/Imperador	Raster	2014
	Pagrus pagrus/Red porgy	Raster	2014
Fish Species Predictive Occurrence Modelling	*Phycis phycis*/Forkbeard	Raster	2014
	Beryx splendens/Splendid alfonsino	Raster	2014
	Pontinus kuhlii/Offshore rockfish	Raster	2014
	Helicolenus dactylopterus/Blackbelly rosefish	Raster	2014
	Pagellus bogaraveo/Red sea bream	Raster	2014
	Beryx decadactylus/Imperador	Raster	2014
Marine Important seabird areas in the Azores	Predicted distribution of *Calonectris diomedea borealis/*Cory's shearwater (May-October)	6xRaster	2009
	Predicted distribution of *Sterna hirundo/*Common tern (May-October)	6xRaster	2009
	Predicted distribution of *Sterna dougallii/*Roseate tern (May-August)	4xRaster	2009
Vulnerable Marine Ecosystems (VME)	VME Score	Raster	2019
	VME Confidence	Raster	2019

Table 3. Spatial Data Sets of Biodiversity.

3.1. Cetaceans / Whales

Raster Dataset Series (24 models): 1704m (1,21Mb)

- *Balaenoptera acutorostrata* (from April to September) – 6 models
- *Balaenoptera borealis* (from April to September) – 6 models
- *Balaenoptera physalus* (from April to September) – 6 models
- *Balaenoptera musculus* (from April to September) – 6 models

Year: 2014

Keywords: cetacean, spatio-temporal distribution, Azores, species distribution models (SDMs), richness, MaxEnt

Summary: Mapped baleen whales habitat suitability and richness in the Azores.

Description: Marine spatial planning and ecological research call for high-resolution species distribution data. However, those data are still not available for most marine large vertebrates. The dynamic nature of oceanographic processes and the wide-ranging behaviour of many marine vertebrates create further difficulties, as distribution data must incorporate both the spatial and temporal dimensions. Cetaceans play an essential role in structuring and maintaining marine ecosystems and face increasing threats from human activities. The Azores holds a high diversity of cetaceans but the information about spatial and temporal patterns of distribution for this marine megafauna group in the region is still very limited. To tackle this issue, we created monthly predictive cetacean distribution maps for spring and summer months, using data collected by the Azores Fisheries Observer Programme between 2004 and 2009. We then combined the individual predictive maps to obtain species richness maps for the same period. Our results reflect a great heterogeneity in distribution among species and within species among different months. This heterogeneity reflects a contrasting influence of oceanographic processes on the distribution of cetacean species. However, some persistent areas of increased species richness could also be identified from our results. We argue that policies aimed at effectively protecting cetaceans and their habitats must include the principle of dynamic ocean management coupled with other area-based management such as marine spatial planning.

This work was supported by FEDER funds, through the Competitiveness Factors Operational Programme - COMPETE, by national funds, through FCT - Foundation for Science and Technology, under project TRACE (PTDC/ MAR/74071/2006), and by regional funds, through DRCT/SRCTE, under projects MAPCET (M2.1.2/F/012/2011) and 2020 (M2.1.2/I/026/2011). We acknowledge funds provided by FCT to MARE, through the strategic project UID/MAR/04292/2013. RP is supported by an FCT postdoctoral grant (SFRH/BPD/108007/2015); MAS is supported by Program Investigator FCT (IF/00943/2013) and MT was supported by a research fellowship under the Exploratory project (IF/00943/2013/CP1199/CT0001) that also paid the fees for this open-access publication. IF/00943/2013 and IF/00943/2013/CP1199/CT0001 are funded by FSE and MCTES, through POPH and QREN.

Credits: IMAR, Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -33.775034 East -22.508365
North 42.225002 South 34.425000

Citation Contacts:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
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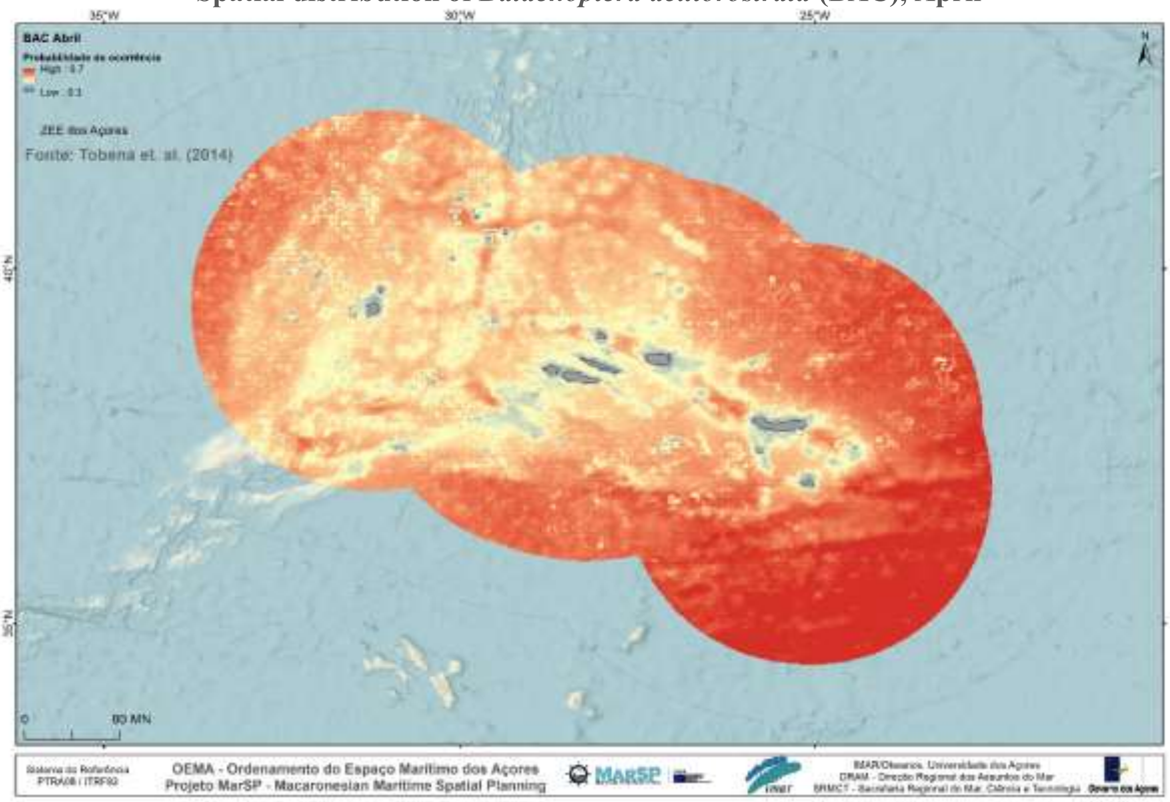
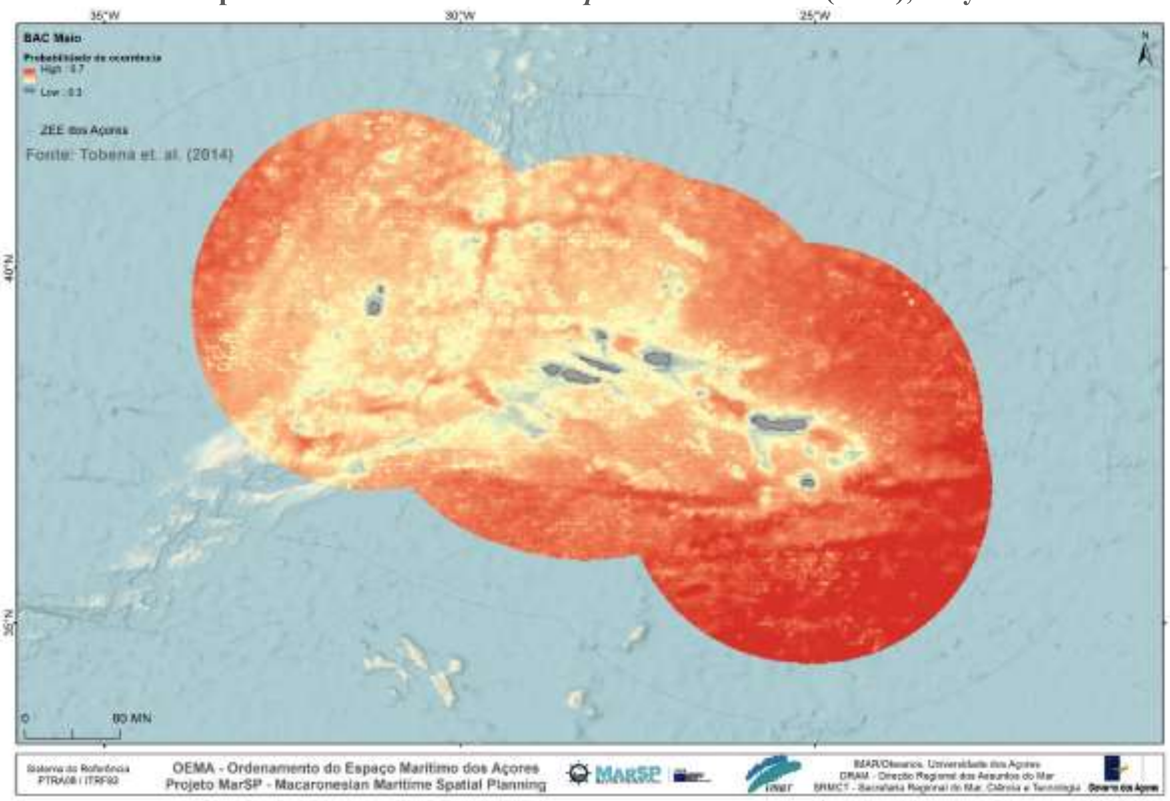
Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3.1.1. *Balaenoptera acutorostrata* (from April to September) – 6 models

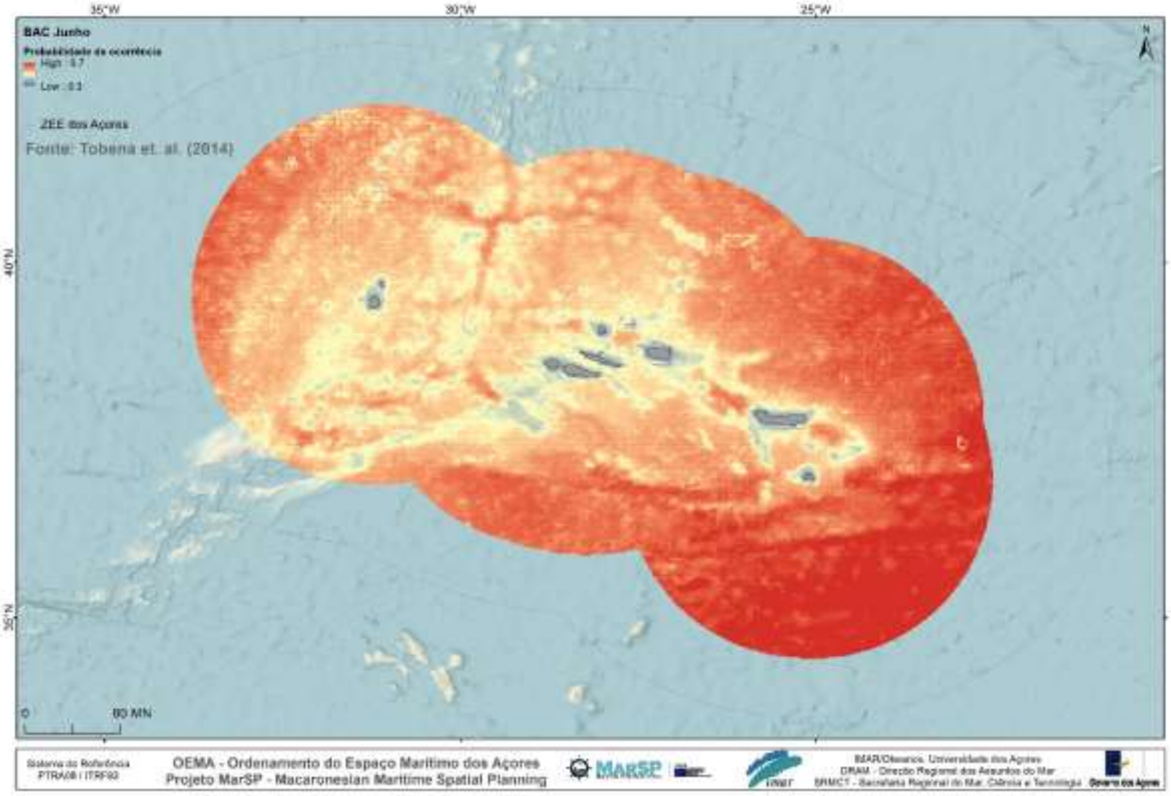
Spatial distribution of *Balaenoptera acutorostrata* (BAC), April



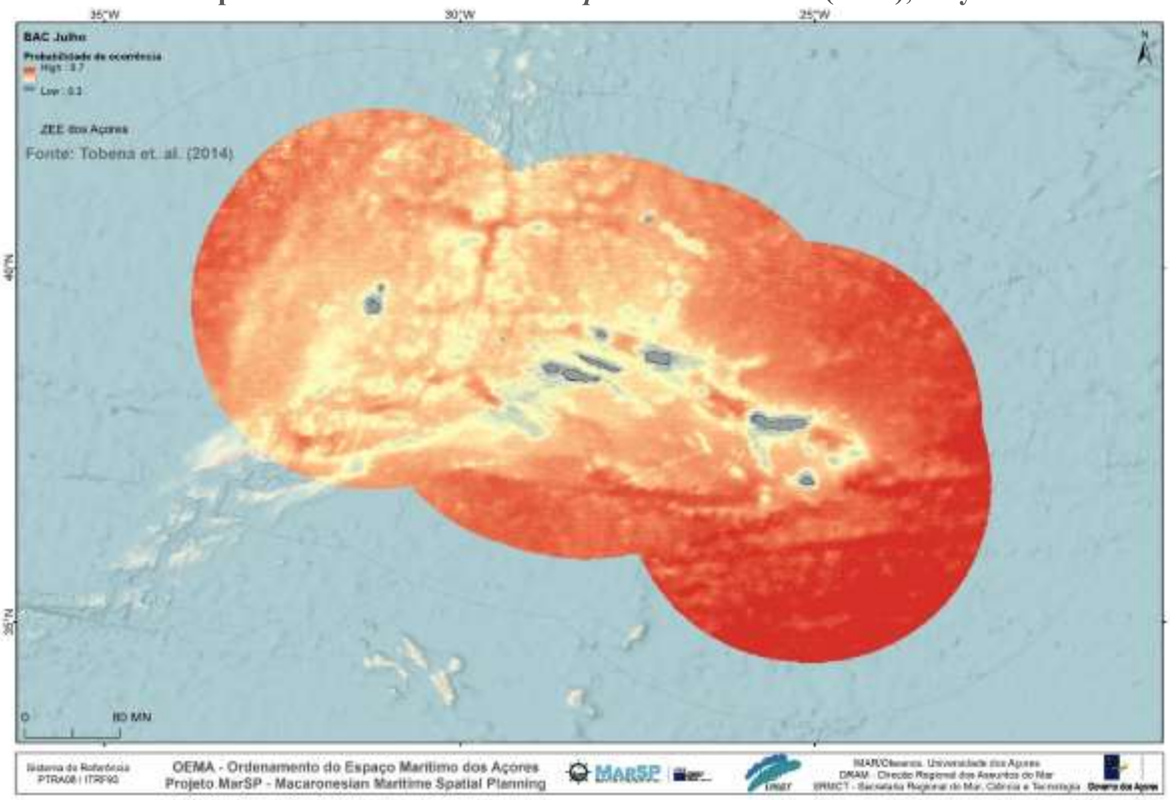
Spatial distribution of *Balaenoptera acutorostrata* (BAC), May



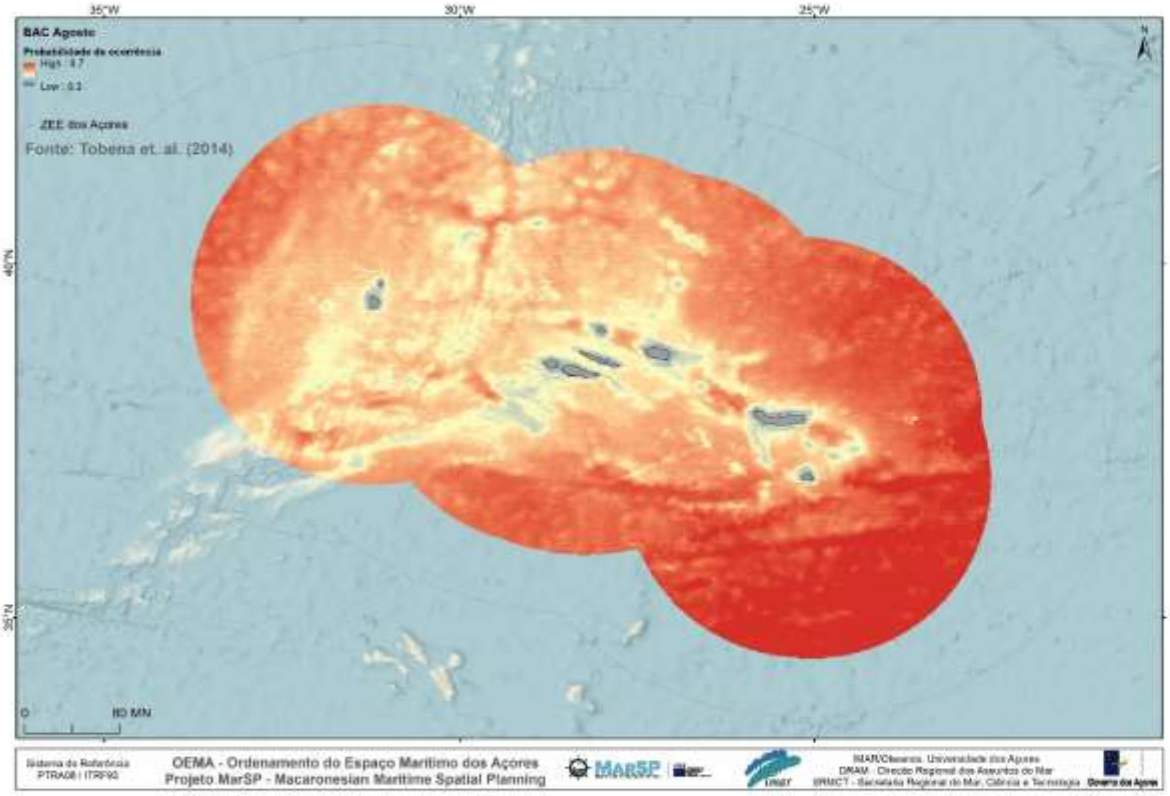
Spatial distribution of *Balaenoptera acutorostrata* (BAC), June



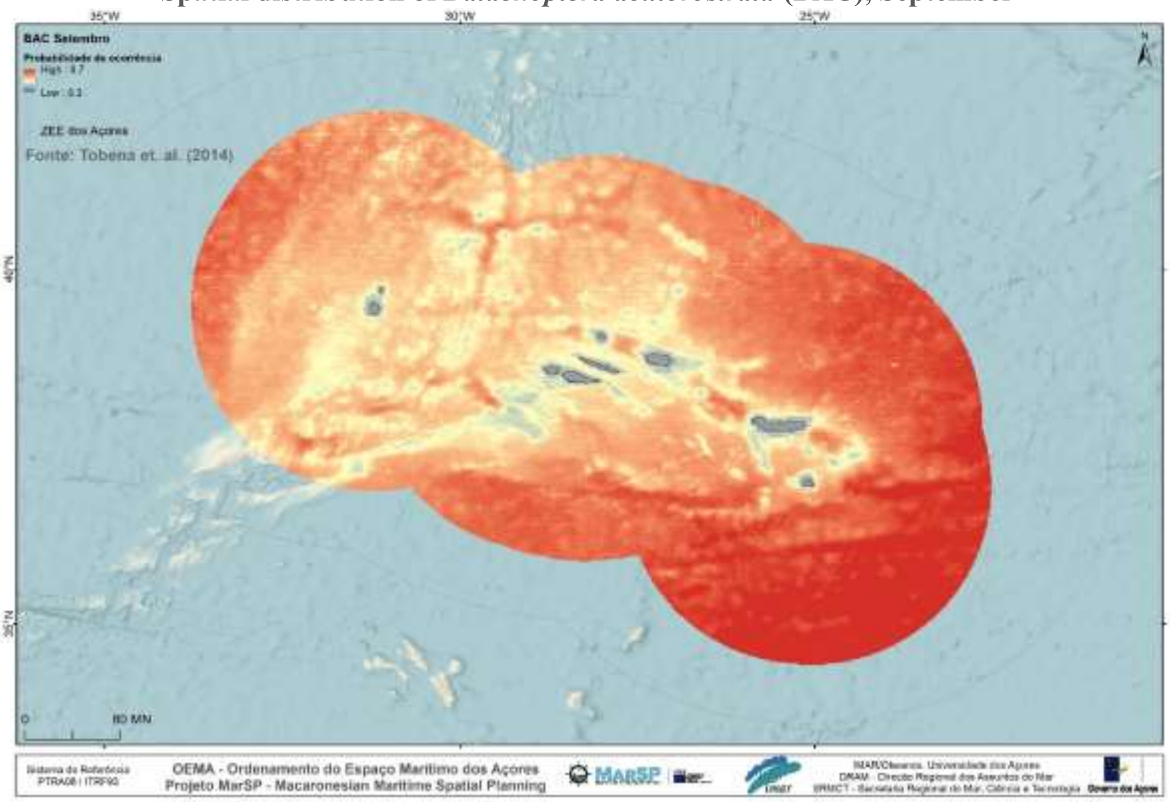
Spatial distribution of *Balaenoptera acutorostrata* (BAC), July



Spatial distribution of *Balaenoptera acutorostrata* (BAC), August

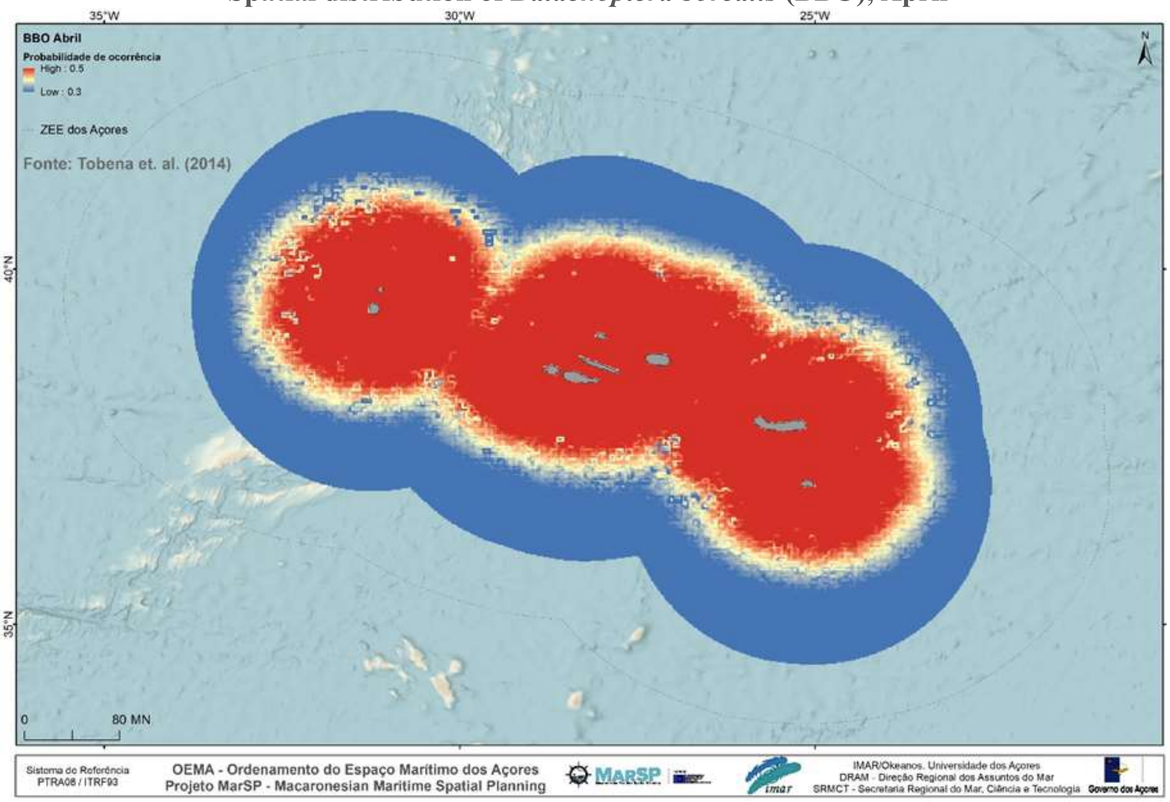


Spatial distribution of *Balaenoptera acutorostrata* (BAC), September

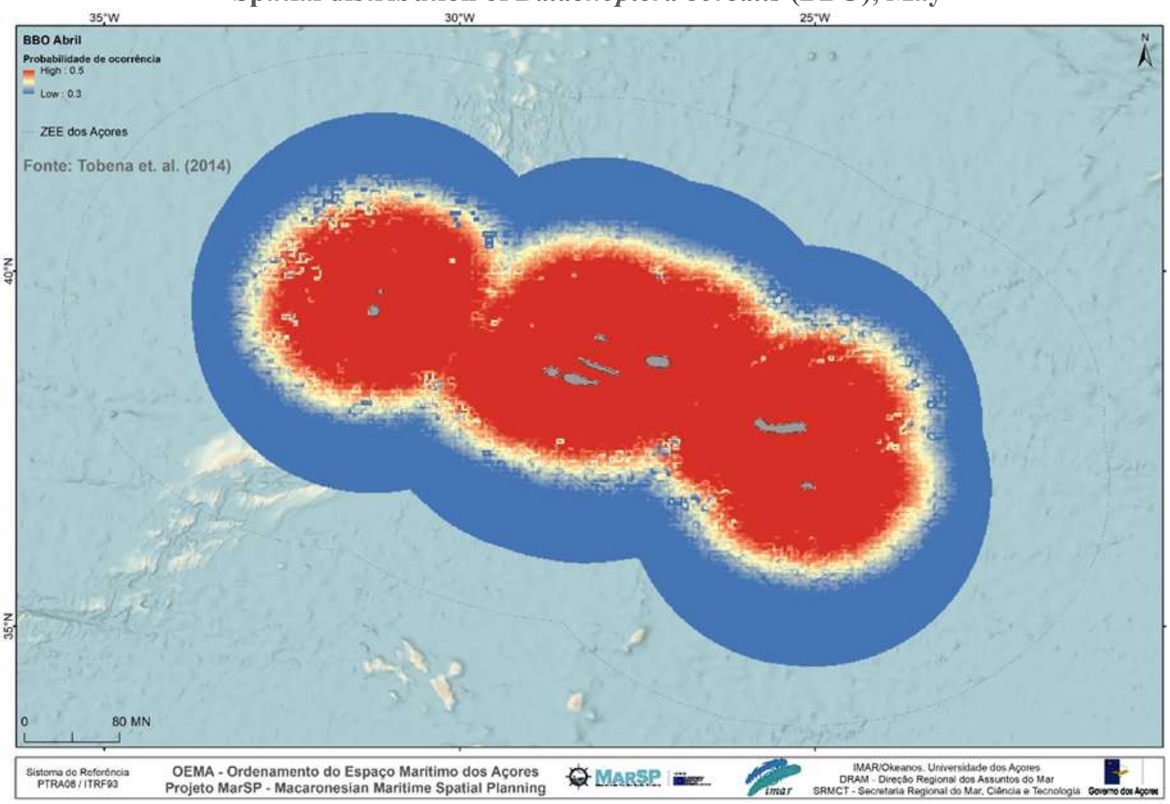


3.1.2. *Balaenoptera borealis* (from April to September) – 6 models

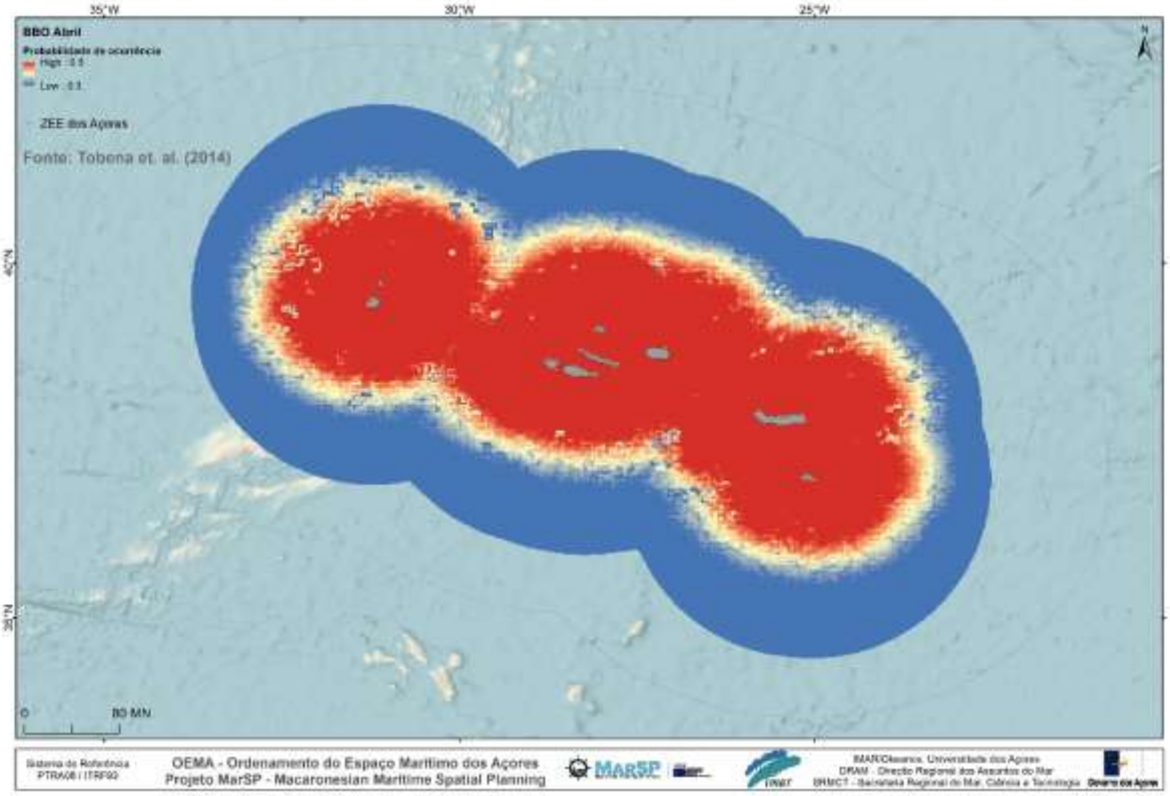
Spatial distribution of *Balaenoptera borealis* (BBO), April



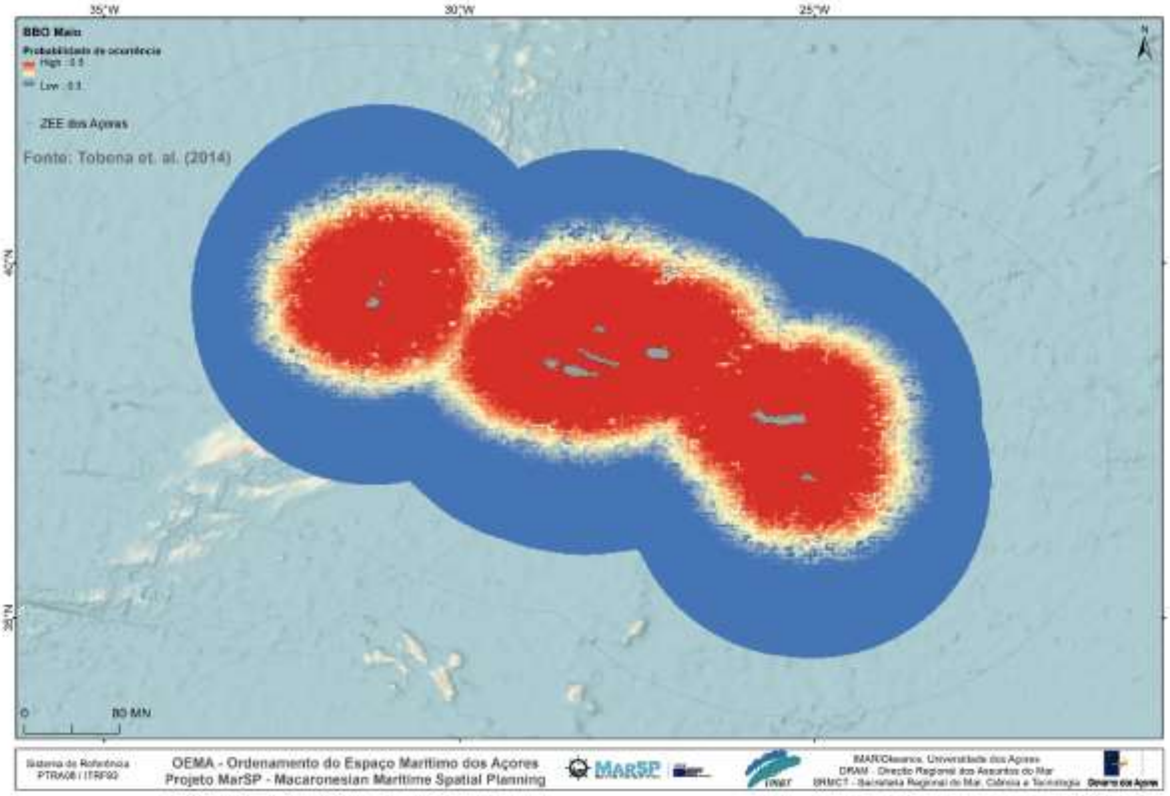
Spatial distribution of *Balaenoptera borealis* (BBO), May



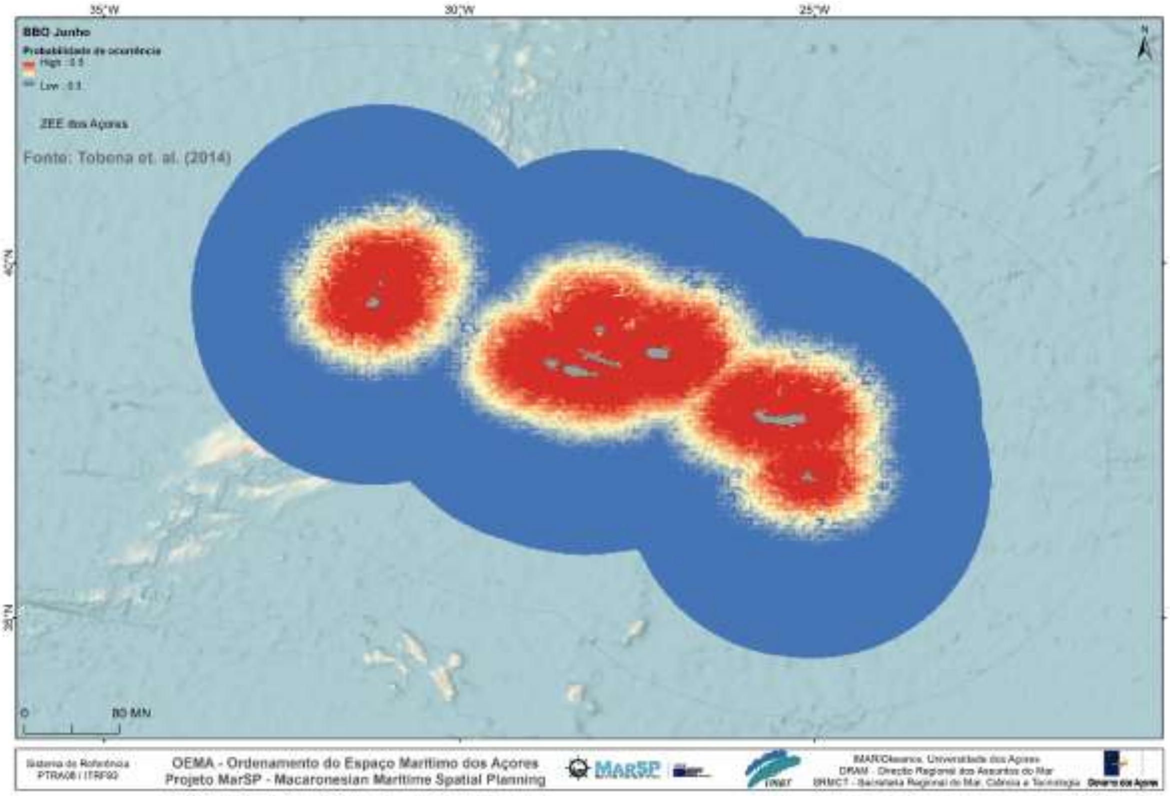
Distribuição Espacial de Baleias: Balaenoptera borealis (BBO), Abril



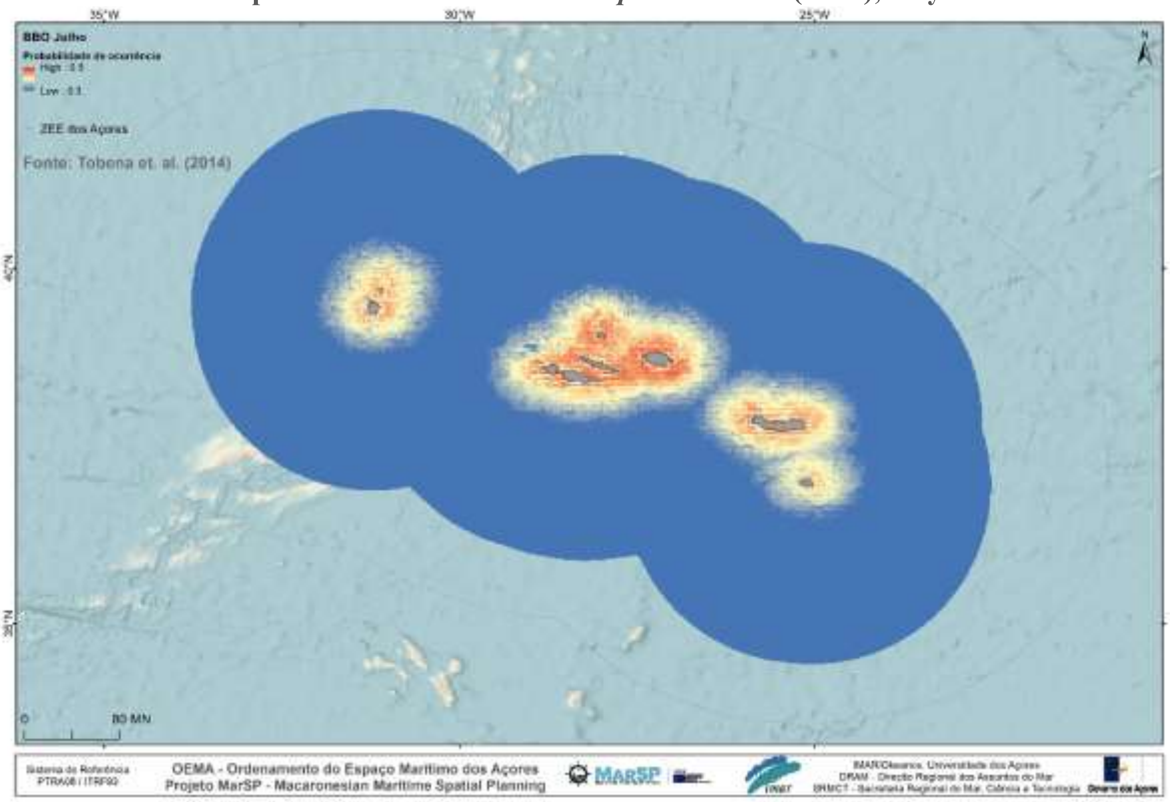
Distribuição Espacial de Baleias: Balaenoptera borealis (BBO), Maio



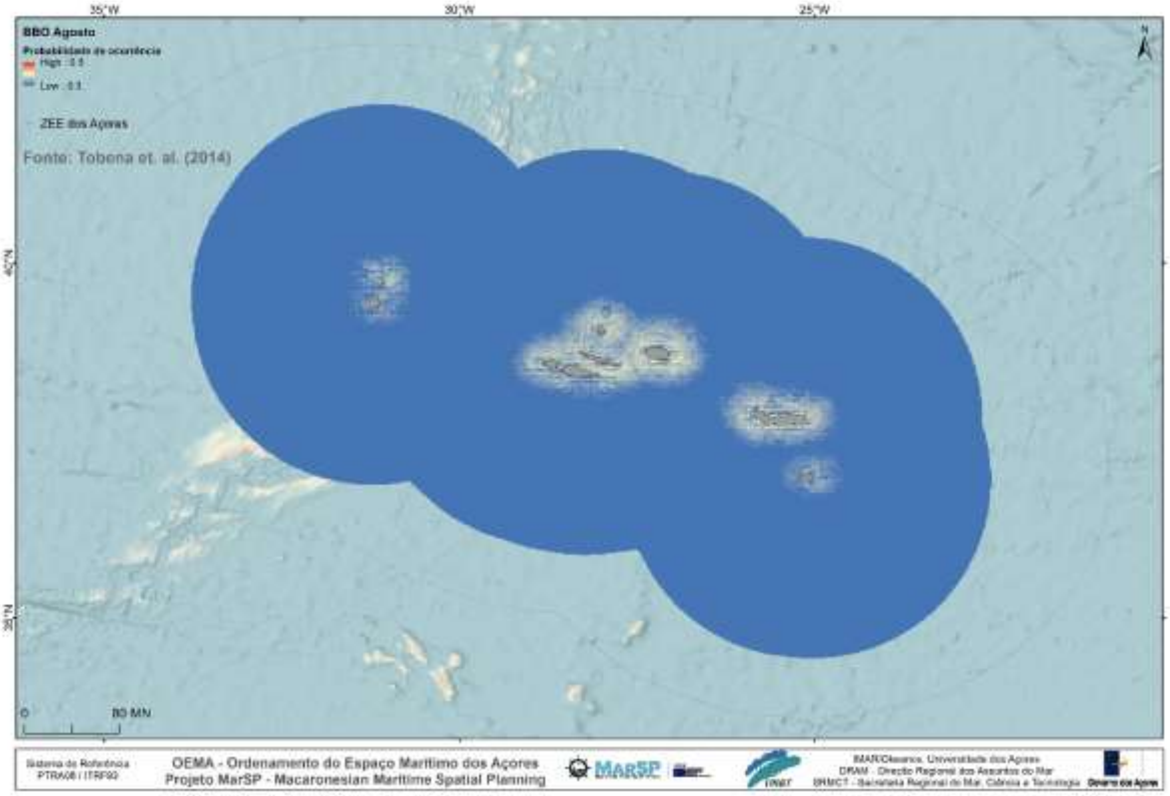
Spatial distribution of *Balaenoptera borealis* (BBO), June



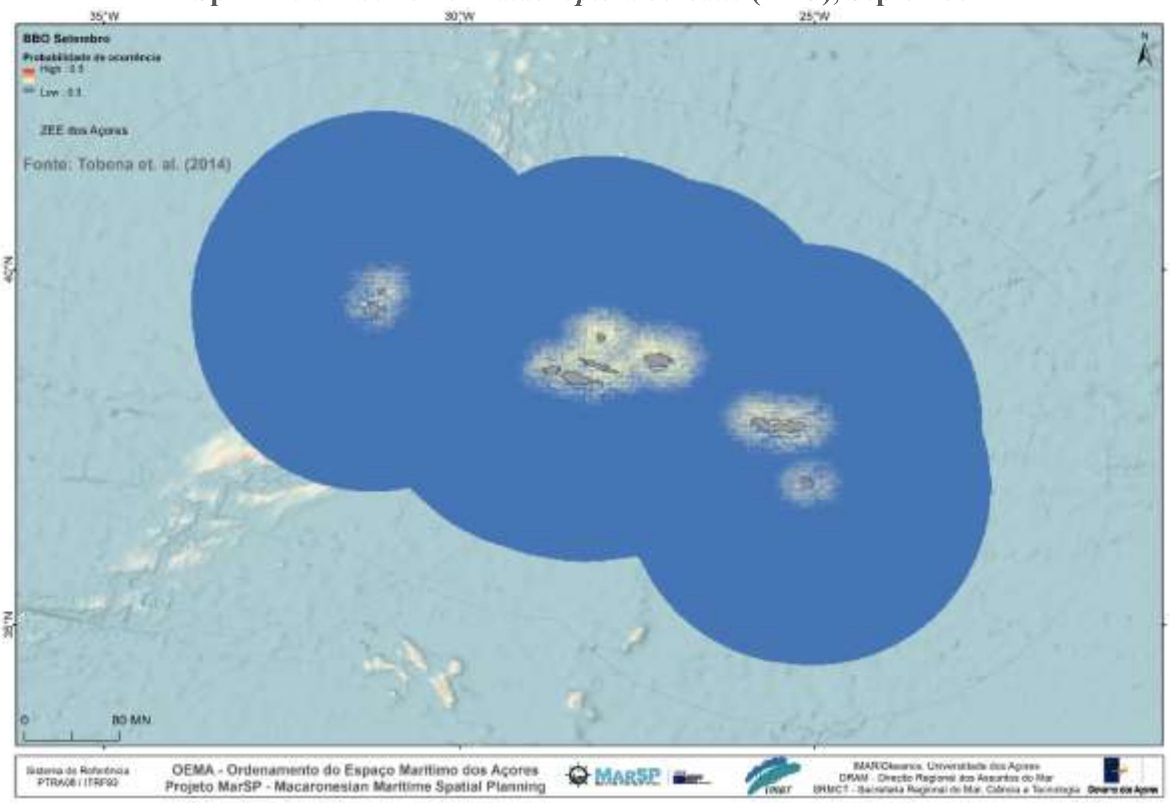
Spatial distribution of *Balaenoptera borealis* (BBO), July



Spatial distribution of *Balaenoptera borealis* (BBO), August

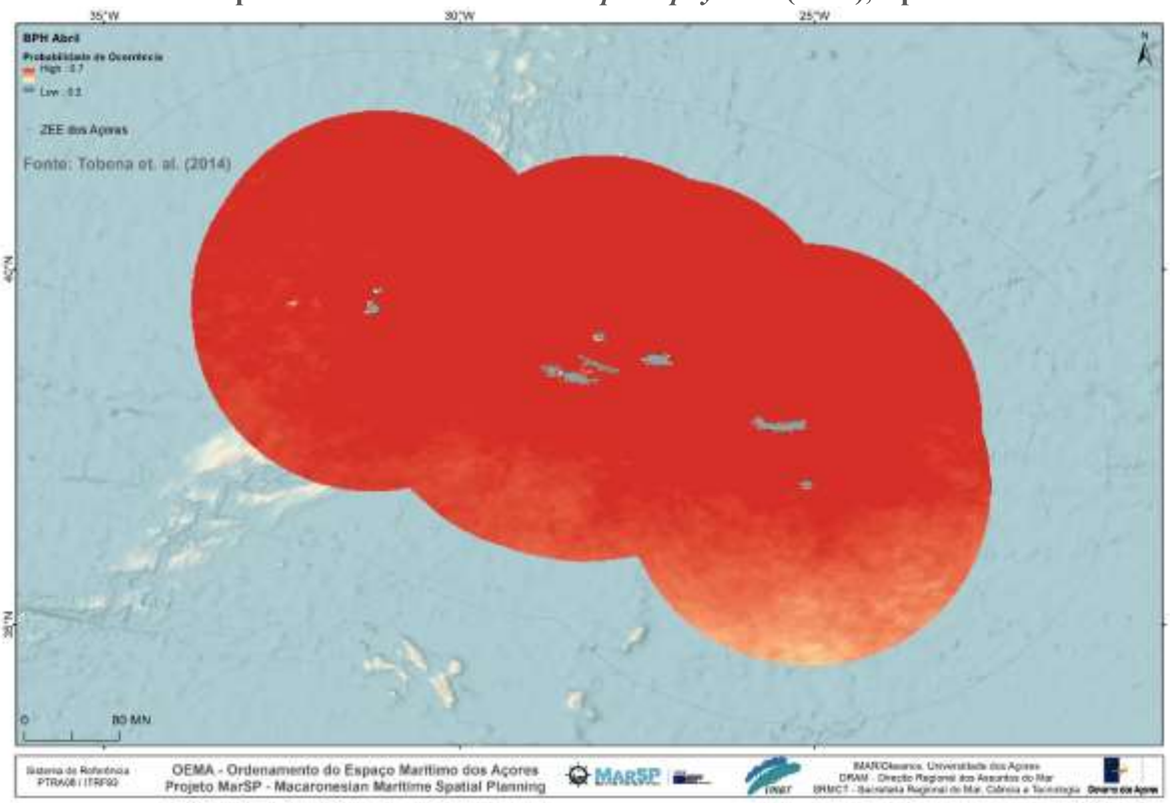


Spatial distribution of *Balaenoptera borealis* (BBO), September

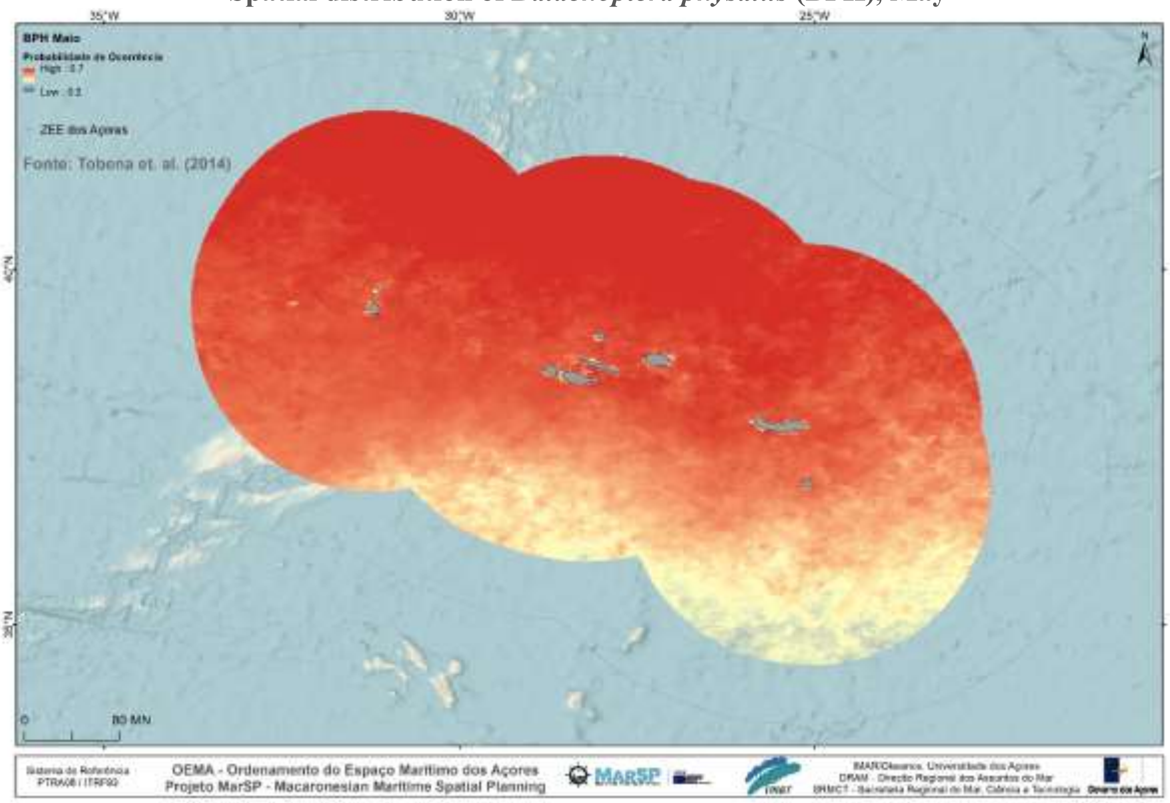


3.1.3. *Balaenoptera physalus* (from April to September) – 6 models

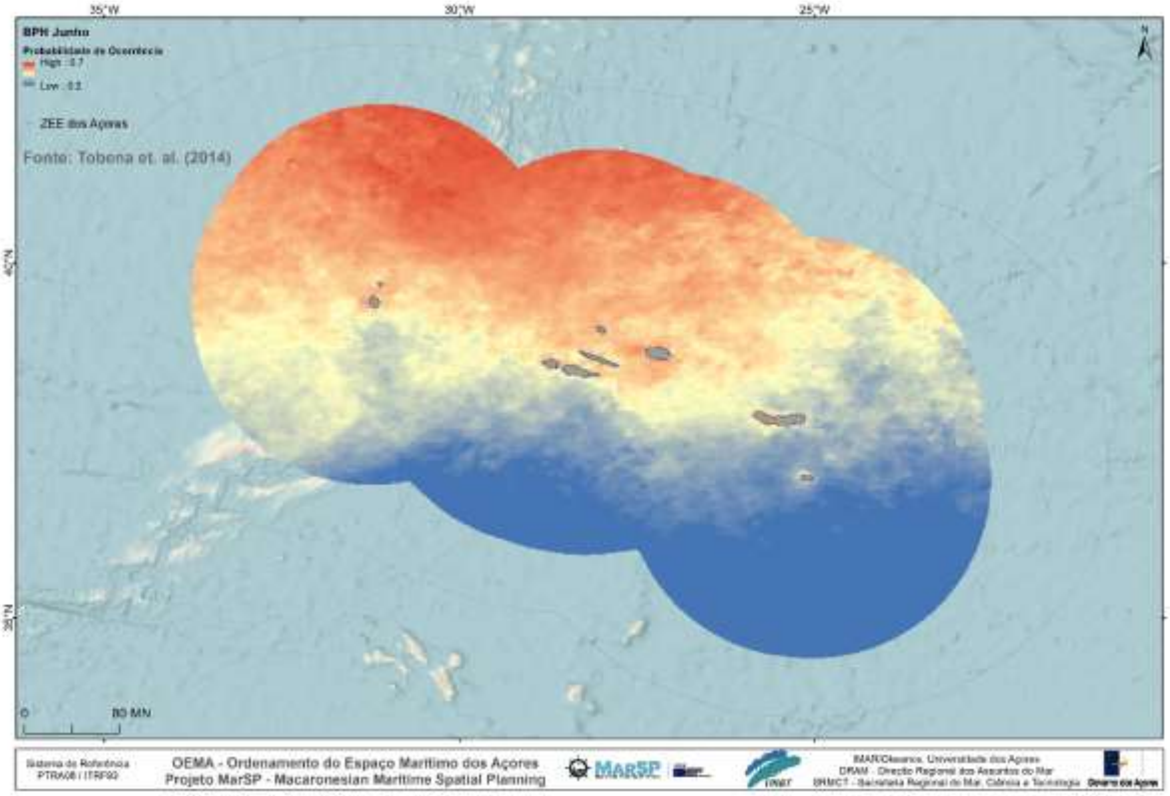
Spatial distribution of *Balaenoptera physalus* (BPH), April



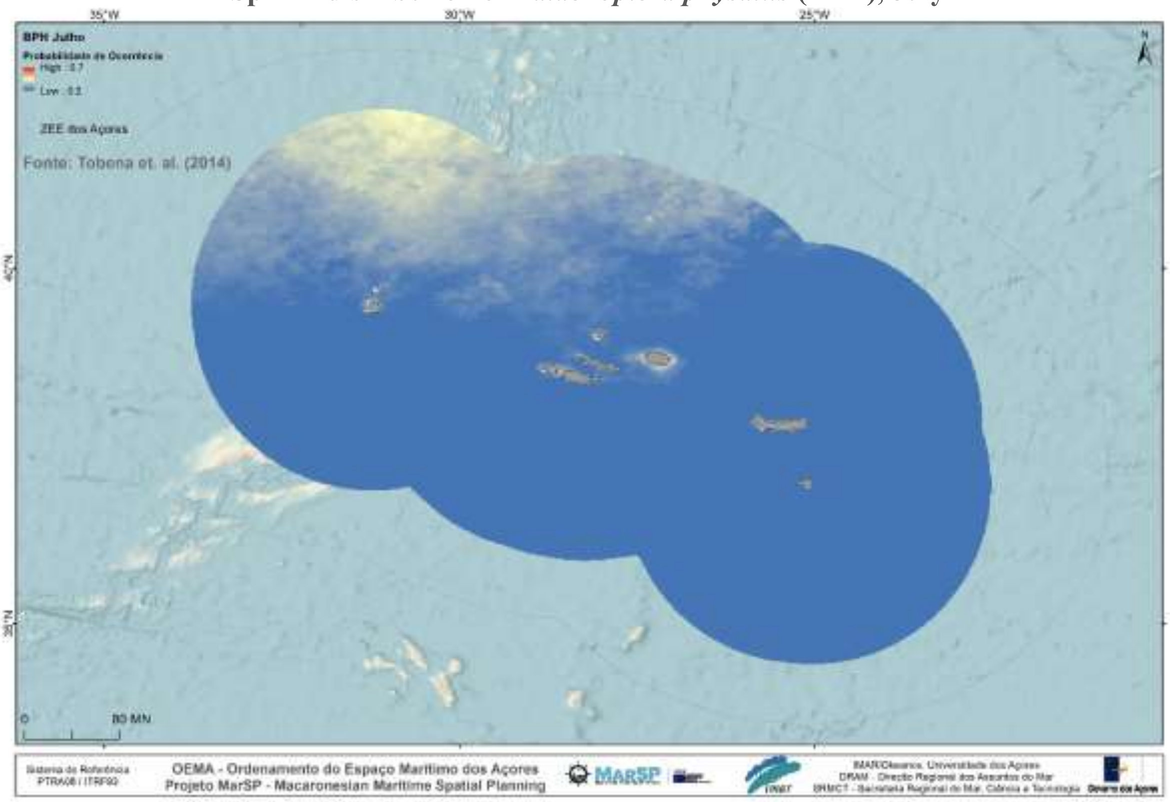
Spatial distribution of *Balaenoptera physalus* (BPH), May



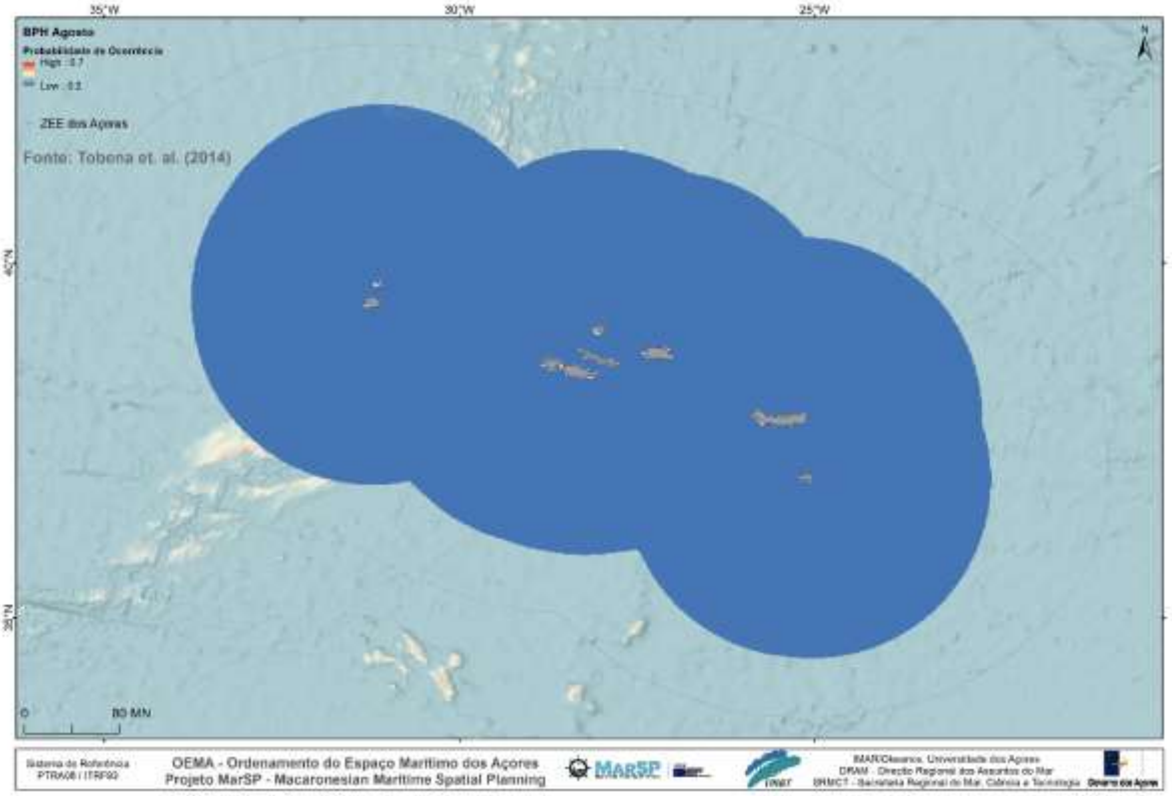
Spatial distribution of *Balaenoptera physalus* (BPH), June



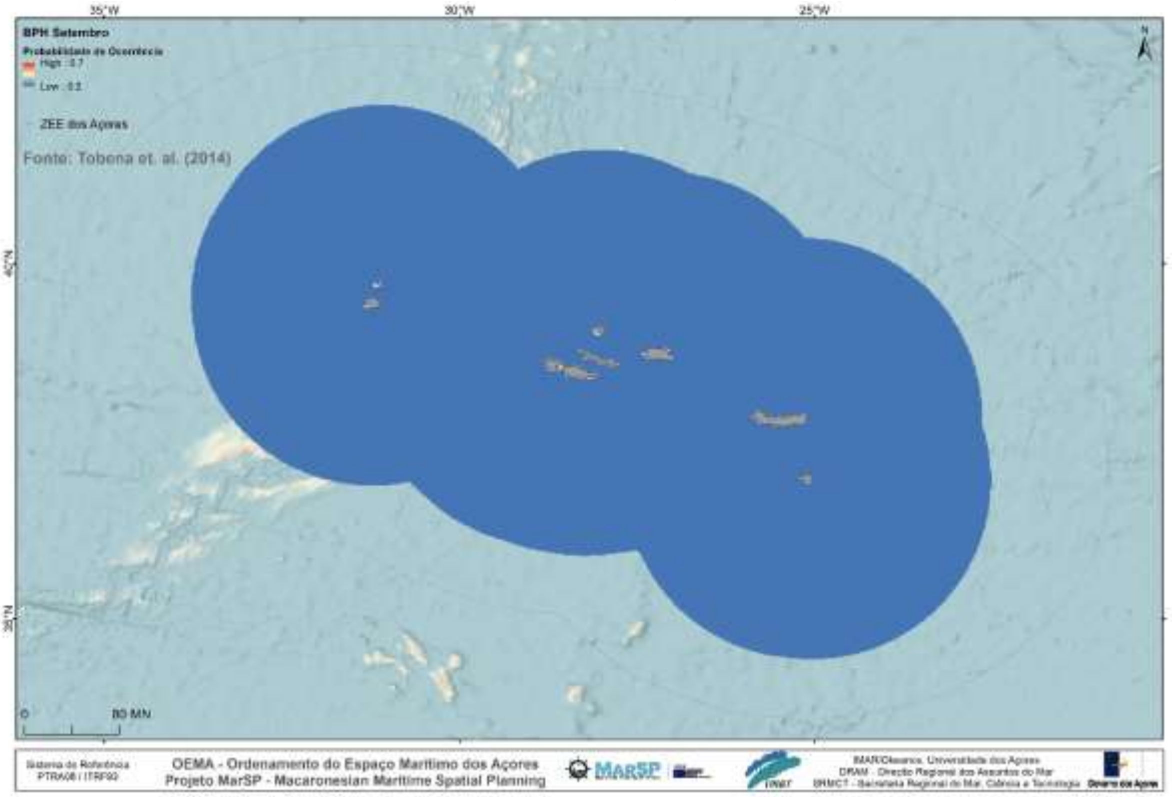
Spatial distribution of *Balaenoptera physalus* (BPH), July



Spatial distribution of *Balaenoptera physalus* (BPH), August

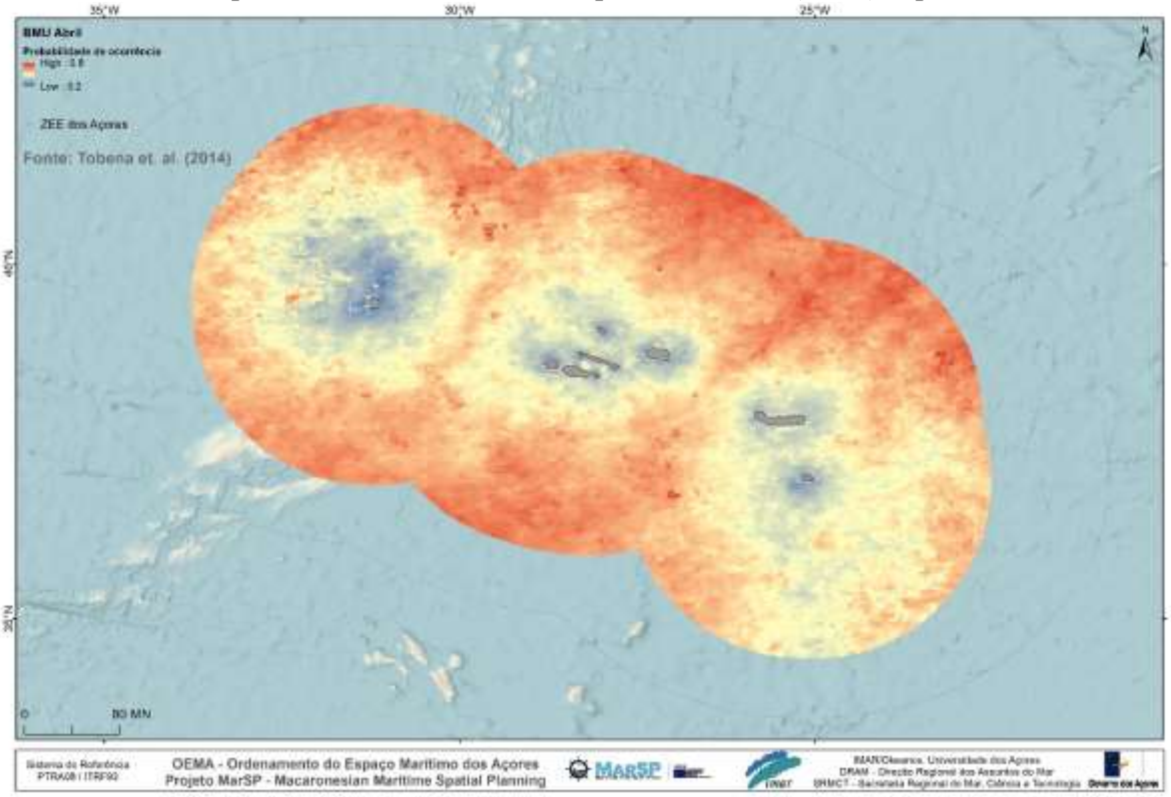


Spatial distribution of *Balaenoptera physalus* (BPH), September

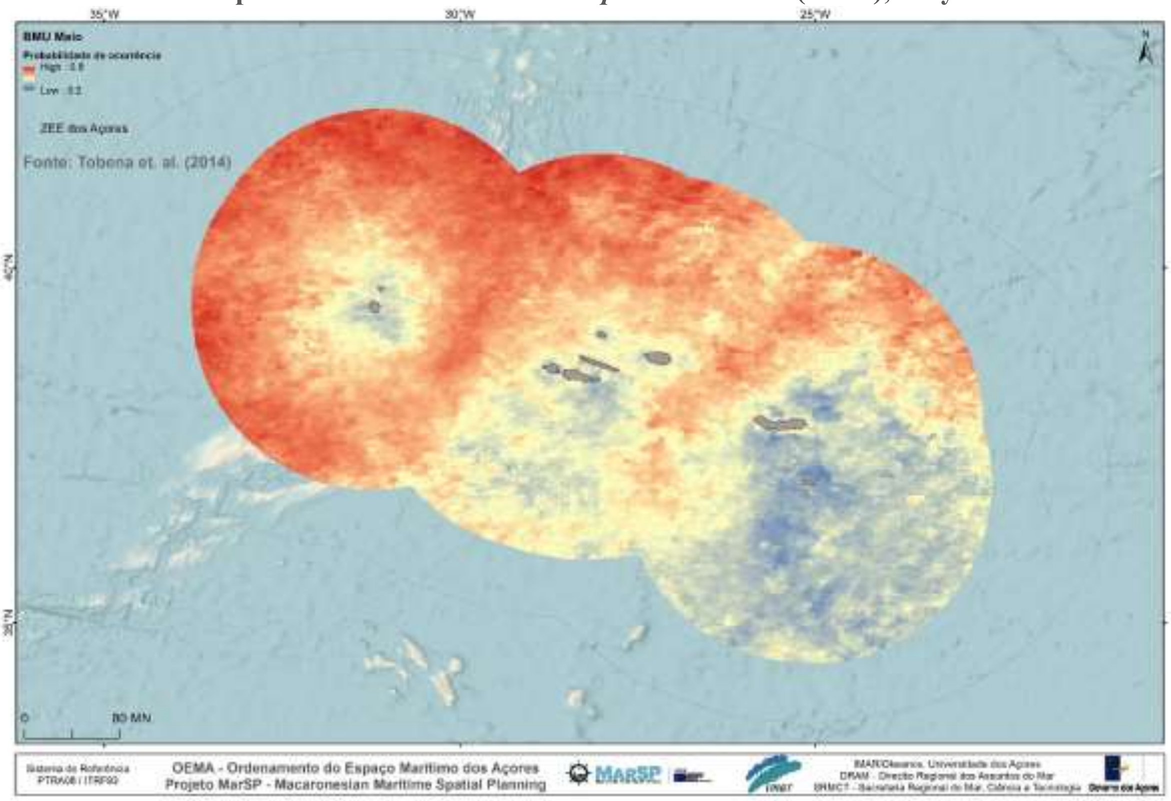


3.1.4. *Balaenoptera musculus* (from April to September) – 6 models

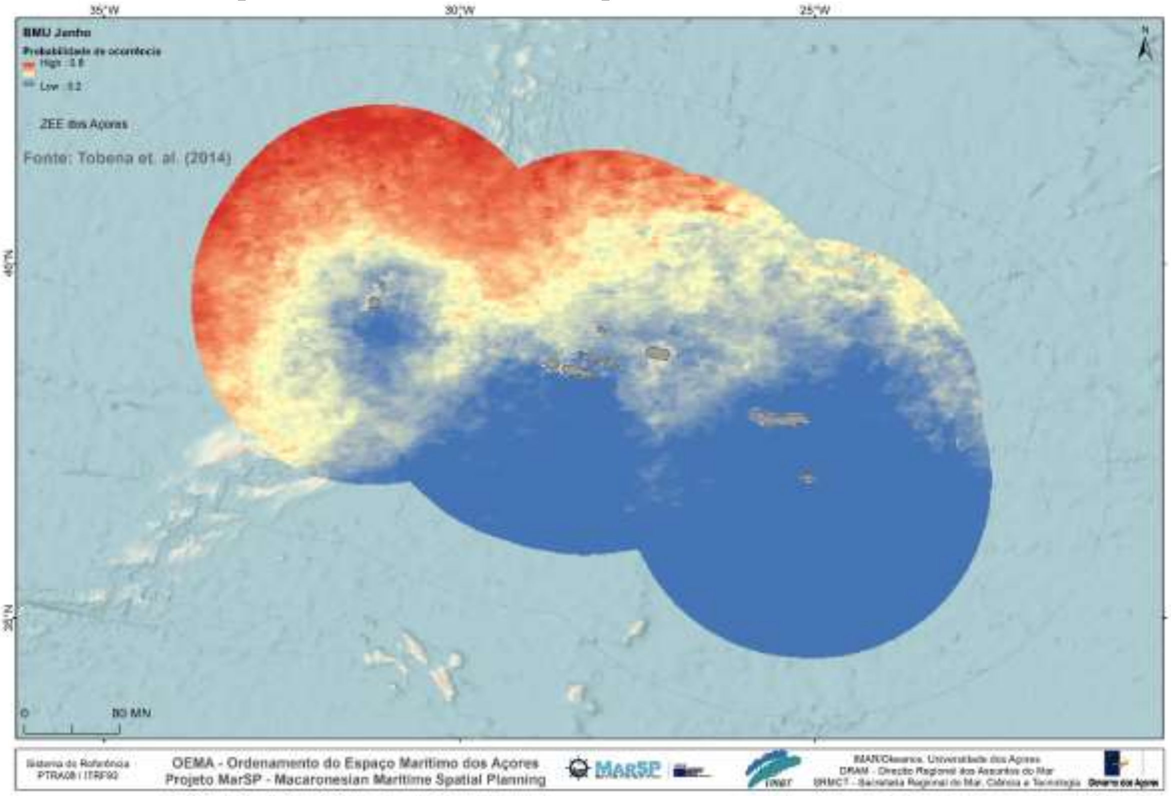
Spatial distribution of *Balaenoptera musculus* (BMU), April



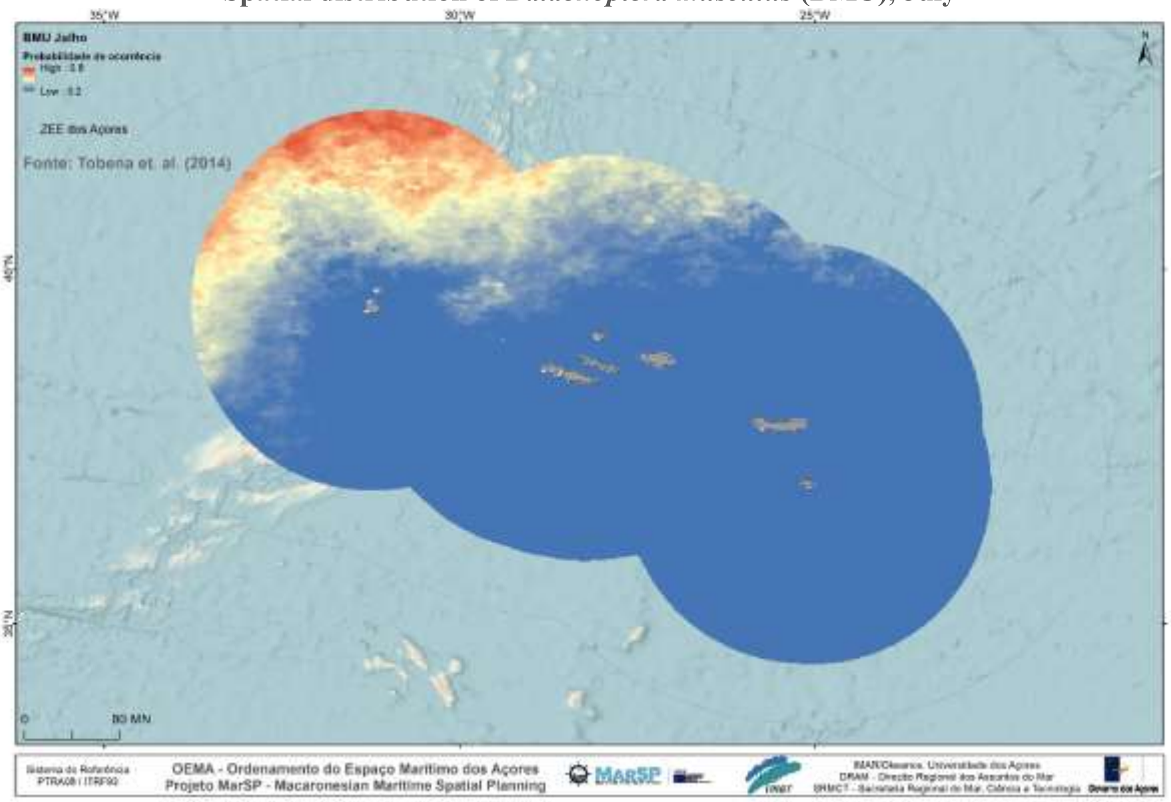
Spatial distribution of *Balaenoptera musculus* (BMU), May



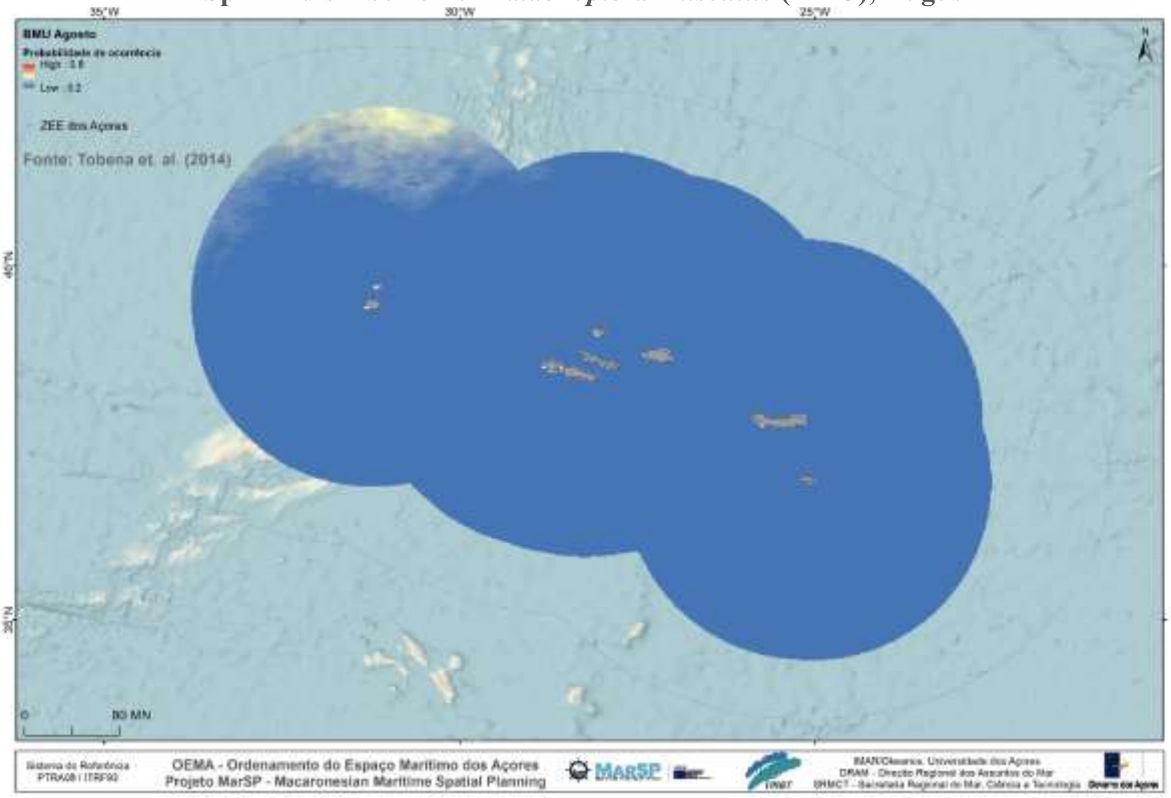
Spatial distribution of *Balaenoptera musculus* (BMU), June



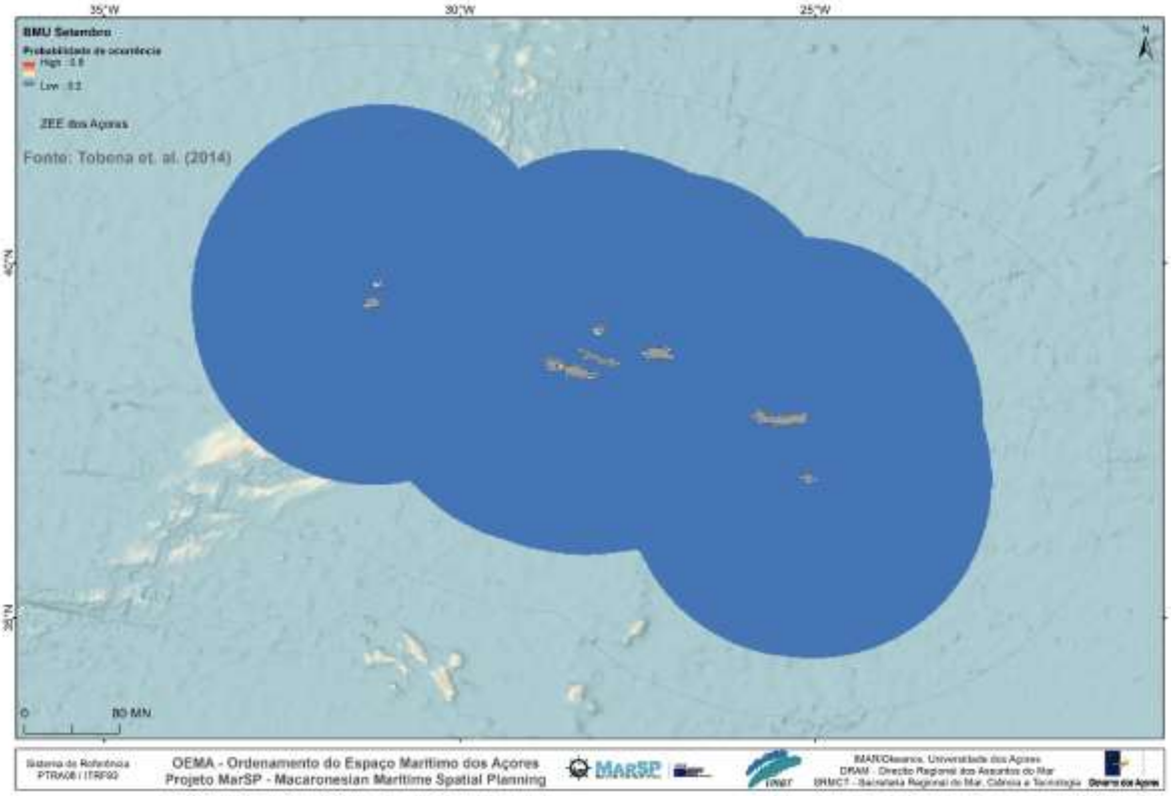
Spatial distribution of *Balaenoptera musculus* (BMU), July



Spatial distribution of *Balaenoptera musculus* (BMU), August



Spatial distribution of *Balaenoptera musculus* (BMU), September



3.2. Cetaceans / Sperm whales and beaked whales

Raster Dataset Series (24 models): 1704m (1,21Mb)

- *Physeter macrocephalus* (from April to September) – 6 models
- *Ziphius cavirostris* (from April to September) – 6 models
- *Hyperoodon ampullatus* (from April to September) – 6 models
- *Mesoplodon* spp. (from April to September) – 6 models

Year: 2014

Keywords: cetacean, spatio-temporal distribution, Azores, sperm whales, species distribution models (SDMs), richness, MaxEnt

Summary: Mapped sperm whales habitat suitability and richness in the Azores.

Description: Marine spatial planning and ecological research call for high-resolution species distribution data. However, those data are still not available for most marine large vertebrates. The dynamic nature of oceanographic processes and the wide-ranging behaviour of many marine vertebrates create further difficulties, as distribution data must incorporate both the spatial and temporal dimensions. Cetaceans play an essential role in structuring and maintaining marine ecosystems and face increasing threats from human activities. The Azores holds a high diversity of cetaceans but the information about spatial and temporal patterns of distribution for this marine megafauna group in the region is still very limited. To tackle this issue, we created monthly predictive cetacean distribution maps for spring and summer months, using data collected by the Azores Fisheries Observer Programme between 2004 and 2009. We then combined the individual predictive maps to obtain species richness maps for the same period. Our results reflect a great heterogeneity in distribution among species and within species among different months. This heterogeneity reflects a contrasting influence of oceanographic processes on the distribution of cetacean species. However, some persistent areas of increased species richness could also be identified from our results. We argue that policies aimed at effectively protecting cetaceans and their habitats must include the principle of dynamic ocean management coupled with other area-based management such as marine spatial planning.

This work was supported by FEDER funds, through the Competitiveness Factors Operational Programme - COMPETE, by national funds, through FCT - Foundation for Science and Technology, under project TRACE (PTDC/ MAR/74071/2006), and by regional funds, through DRCT/SRCTE, under projects MAPCET (M2.1.2/F/012/2011) and 2020 (M2.1.2/I/026/2011). We acknowledge funds provided by FCT to MARE, through the strategic project UID/MAR/04292/2013. RP is supported by an FCT postdoctoral grant (SFRH/BPD/108007/2015); MAS is supported by Program Investigator FCT (IF/00943/2013) and MT was supported by a research fellowship under the Exploratory project (IF/00943/2013/CP1199/CT0001) that also paid the fees for this open-access publication. IF/00943/2013 and IF/00943/2013/CP1199/CT0001 are funded by FSE and MCTES, through POPH and QREN.

Credits: IMAR, Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -33.775034 East -22.508365
North 42.225002 South 34.425000

Citation Contacts:
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E-MAIL ADDRESS rcabprieto@gmail.com

Point of Contact:
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
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XY TOLERANCE 8.983152841195215e-09
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M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
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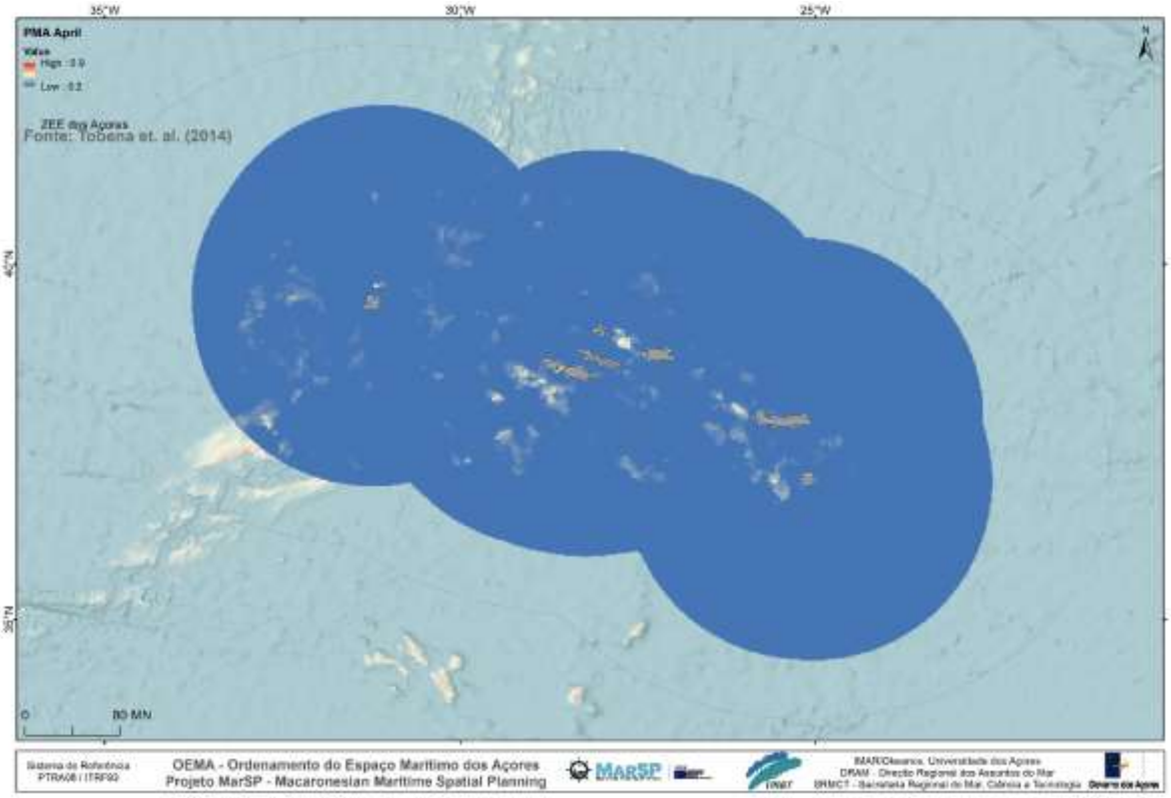
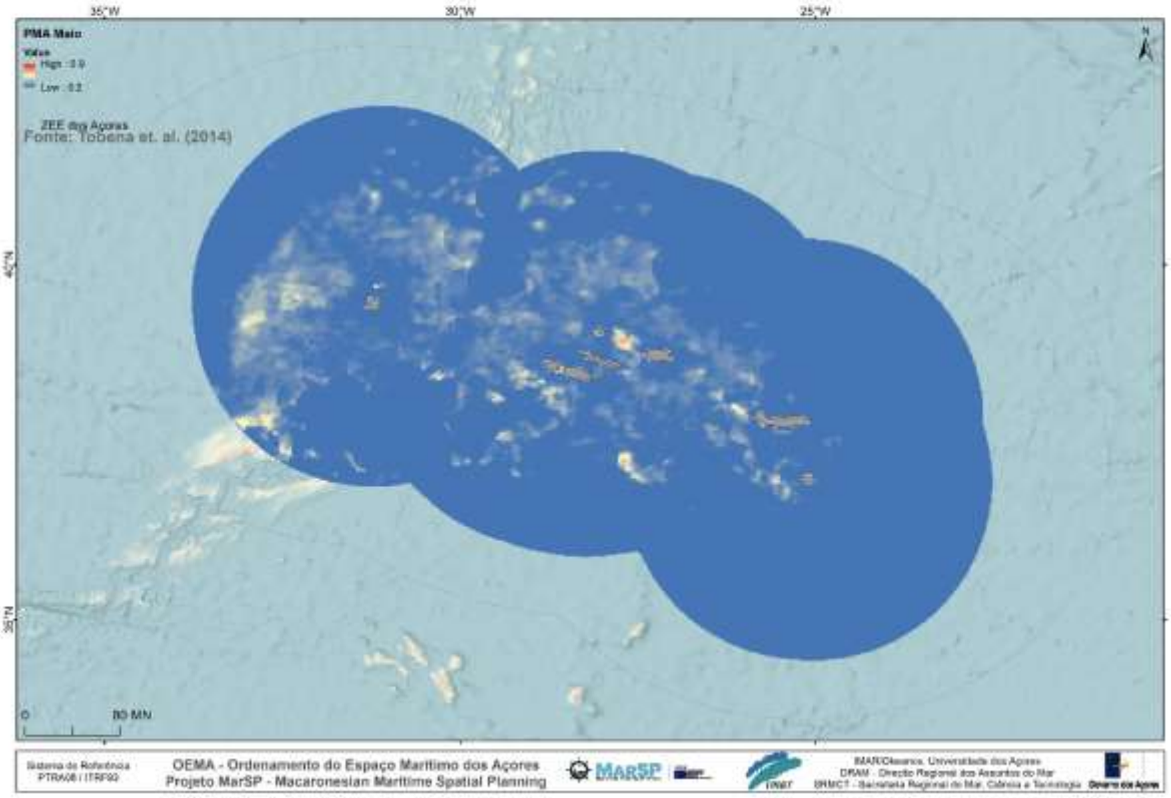
3.2.1. *Physeter macrocephalus* (from April to September) – 6 models

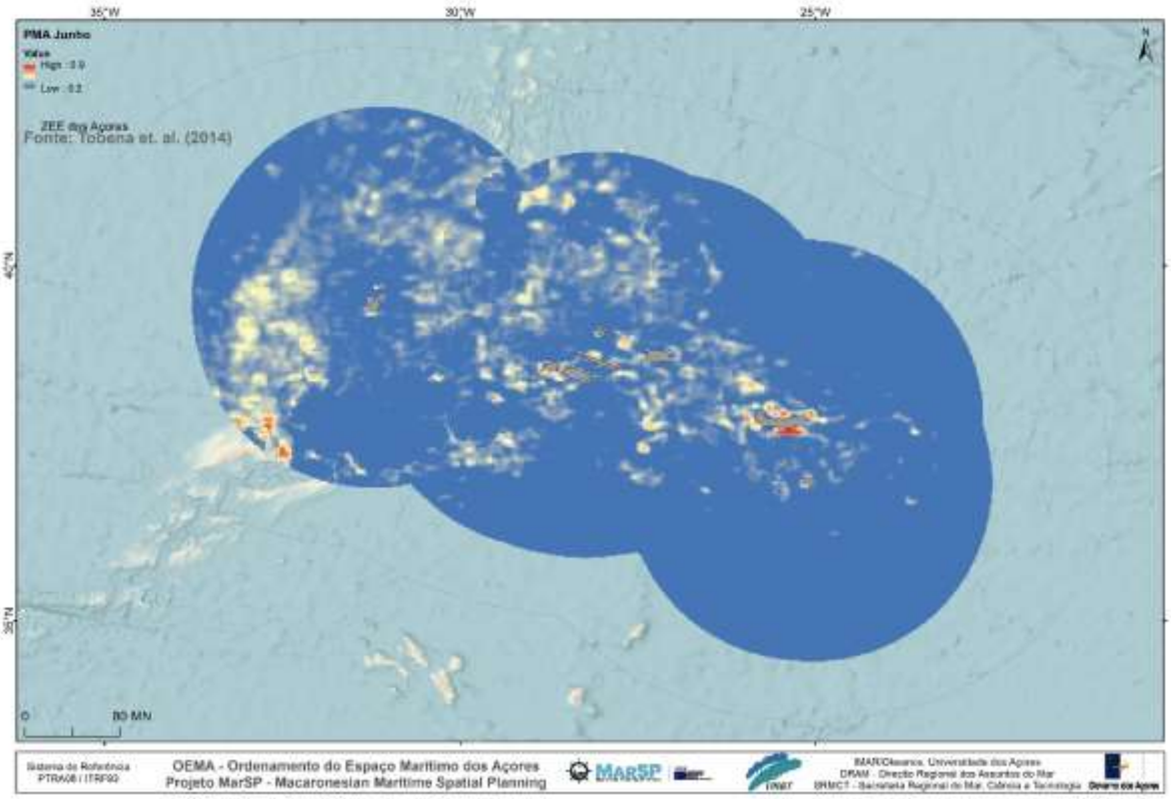
Spatial distribution of *Physeter macrocephalus* (PMA), April



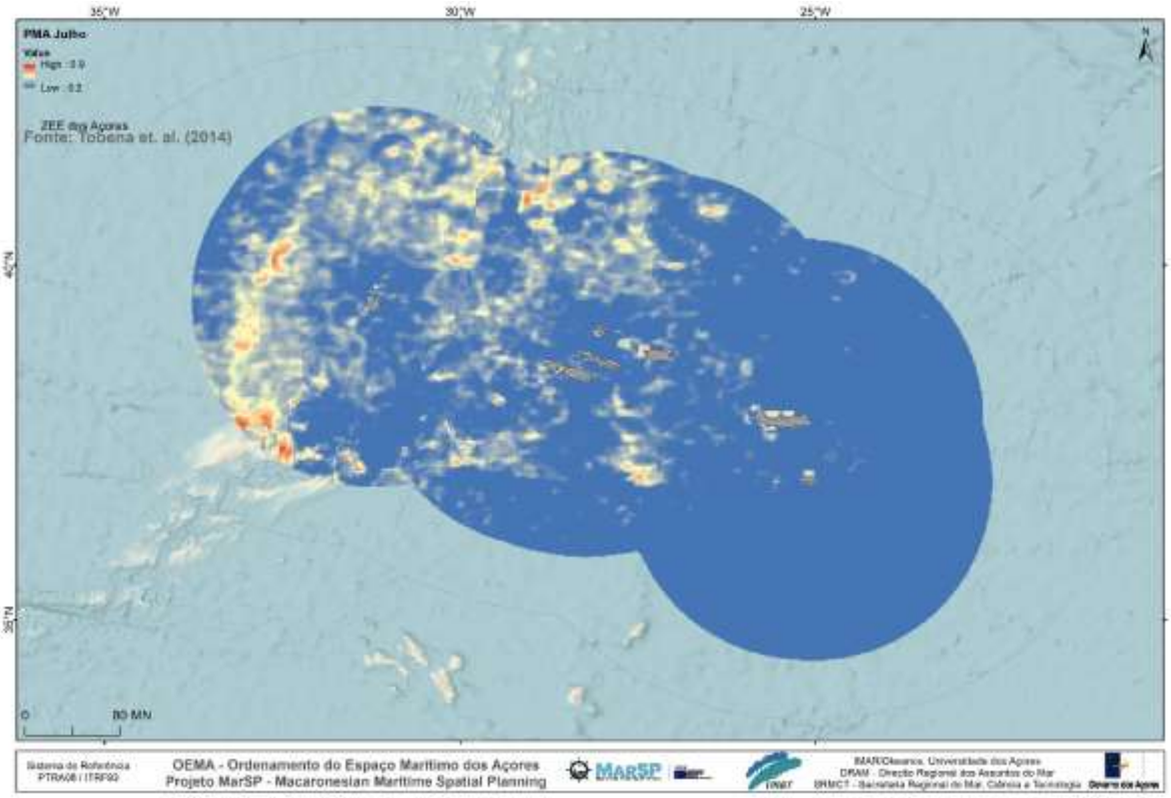
Spatial distribution of *Physeter macrocephalus* (PMA), May



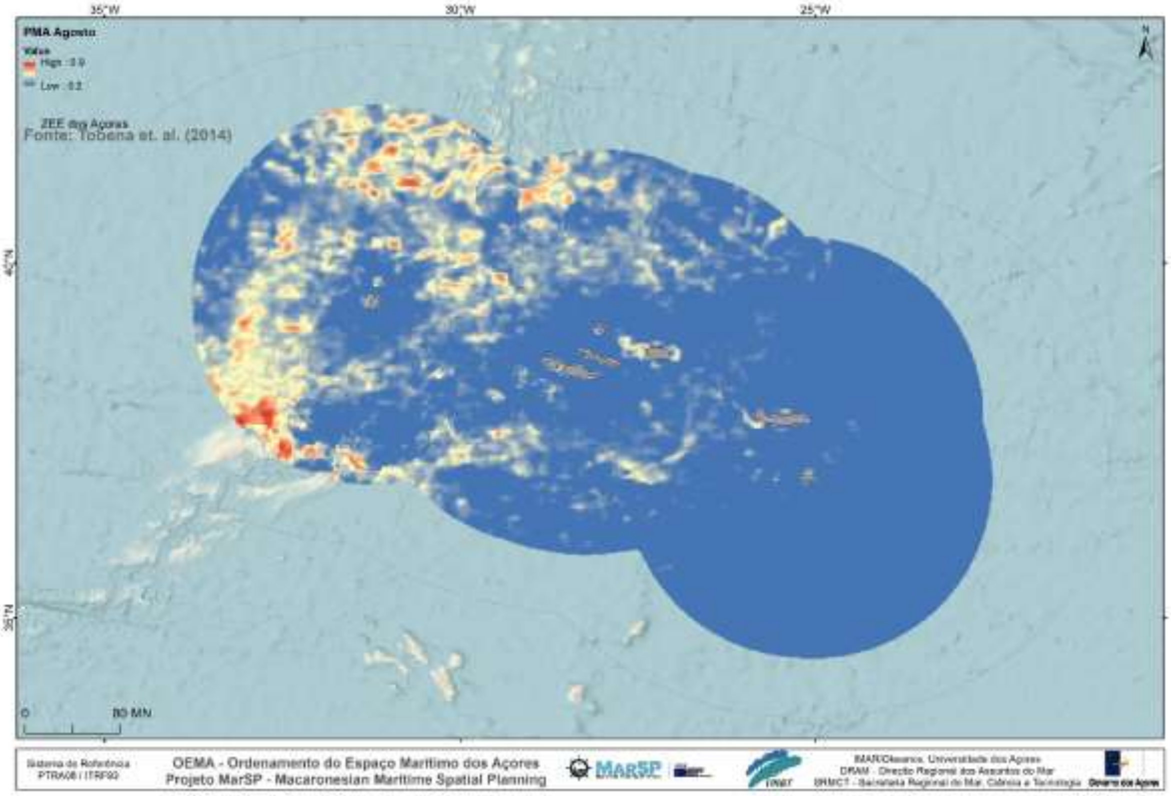
Spatial distribution of *Physeter macrocephalus* (PMA), June



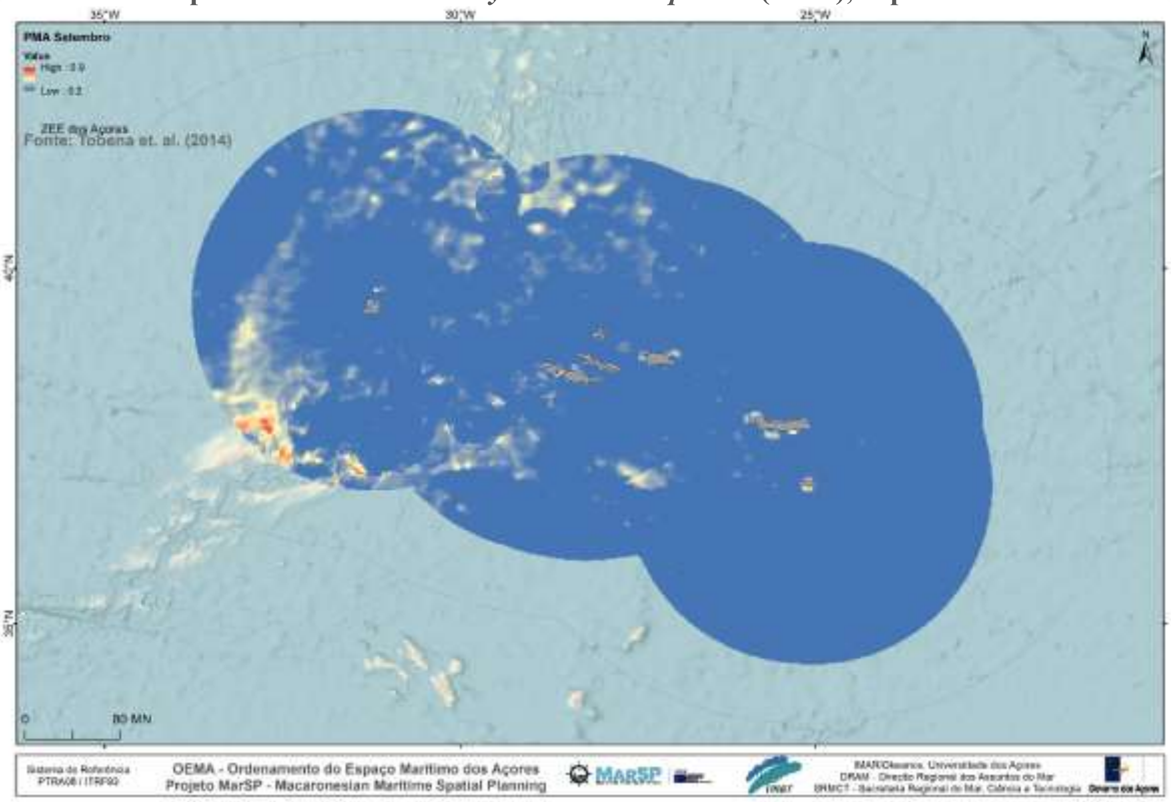
Spatial distribution of *Physeter macrocephalus* (PMA), July



Spatial distribution of *Physeter macrocephalus* (PMA), August

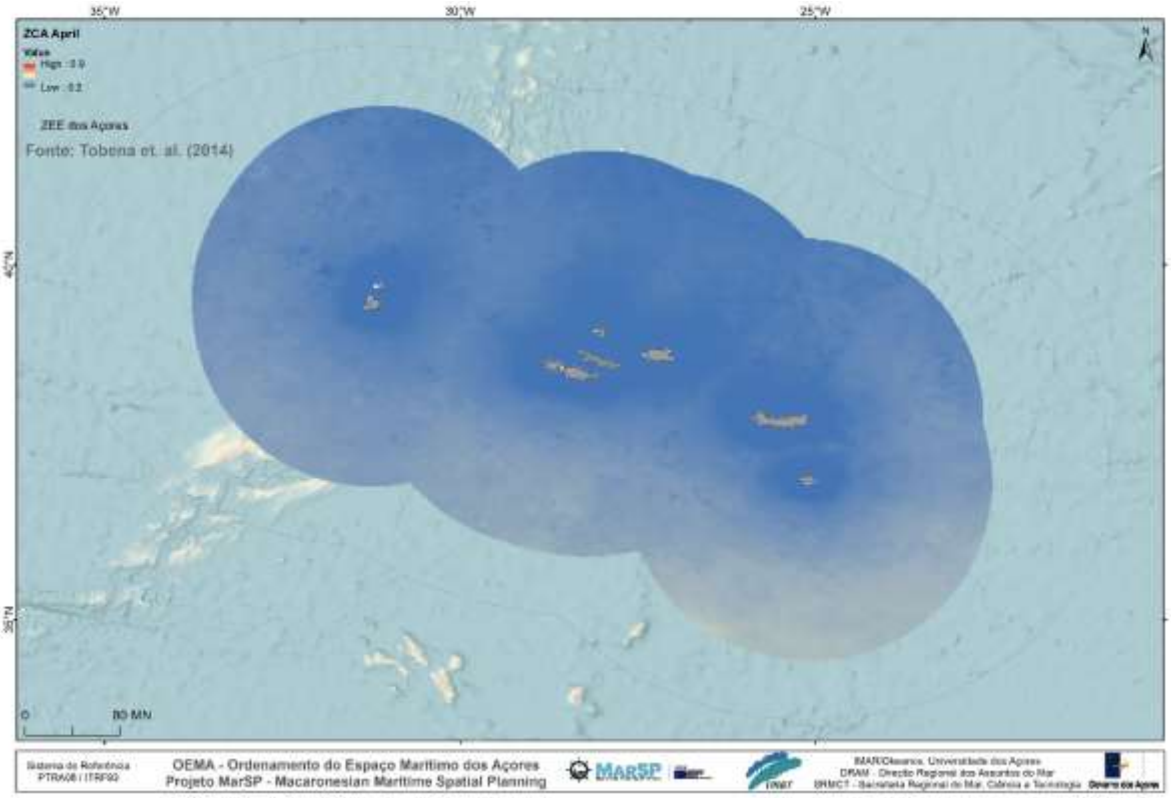


Spatial distribution of *Physeter macrocephalus* (PMA), September

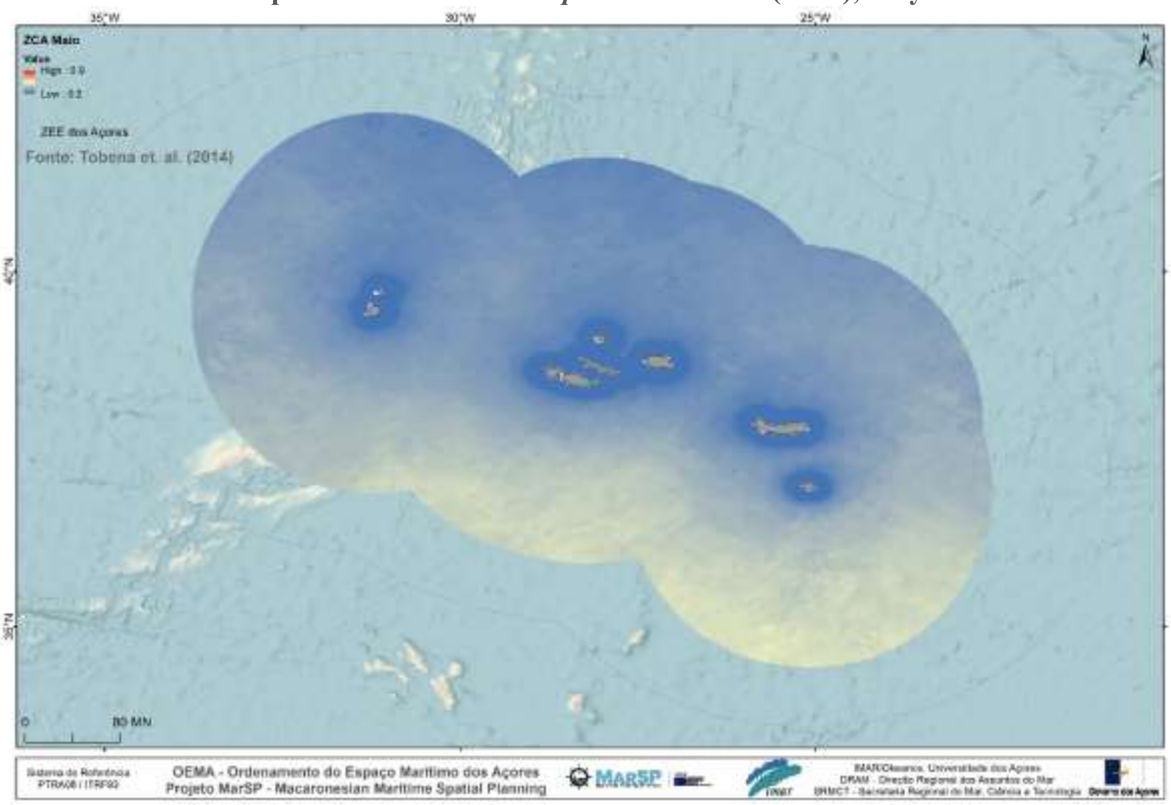


3.2.2. *Ziphius cavirostris* (from April to September) – 6 models

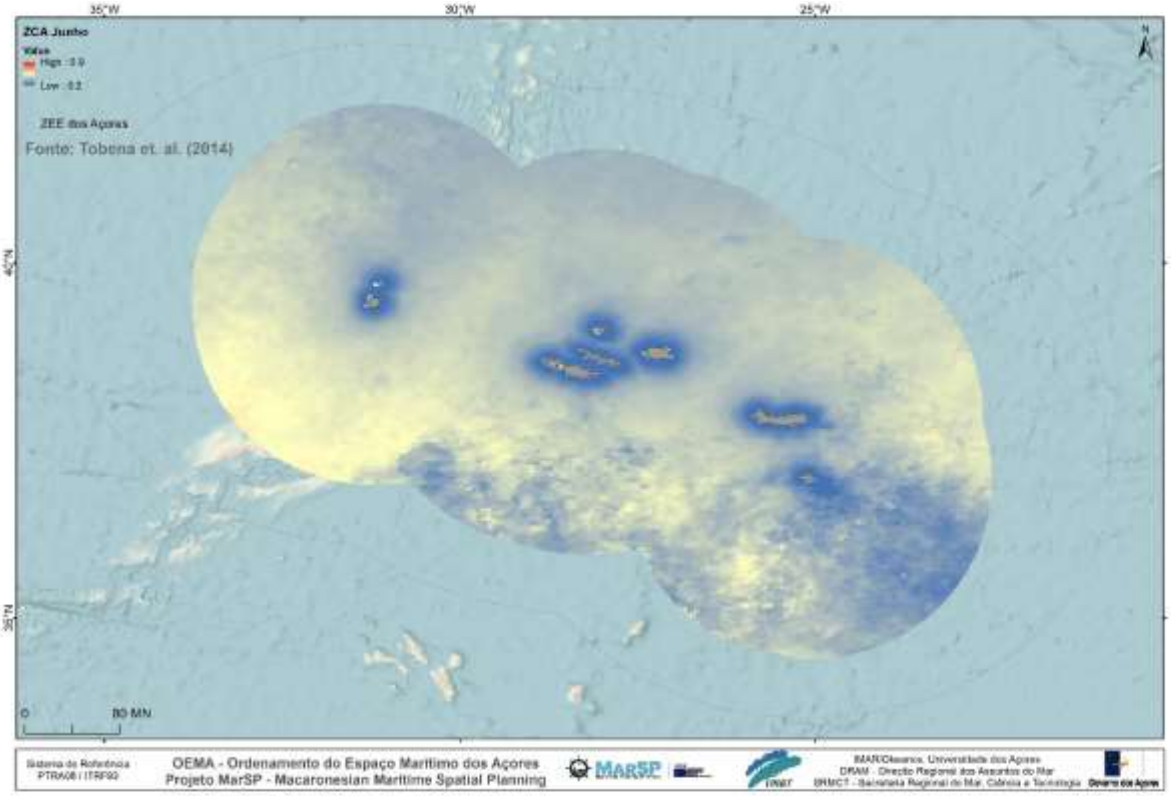
Spatial distribution of *Ziphius cavirostris* (ZCA), April



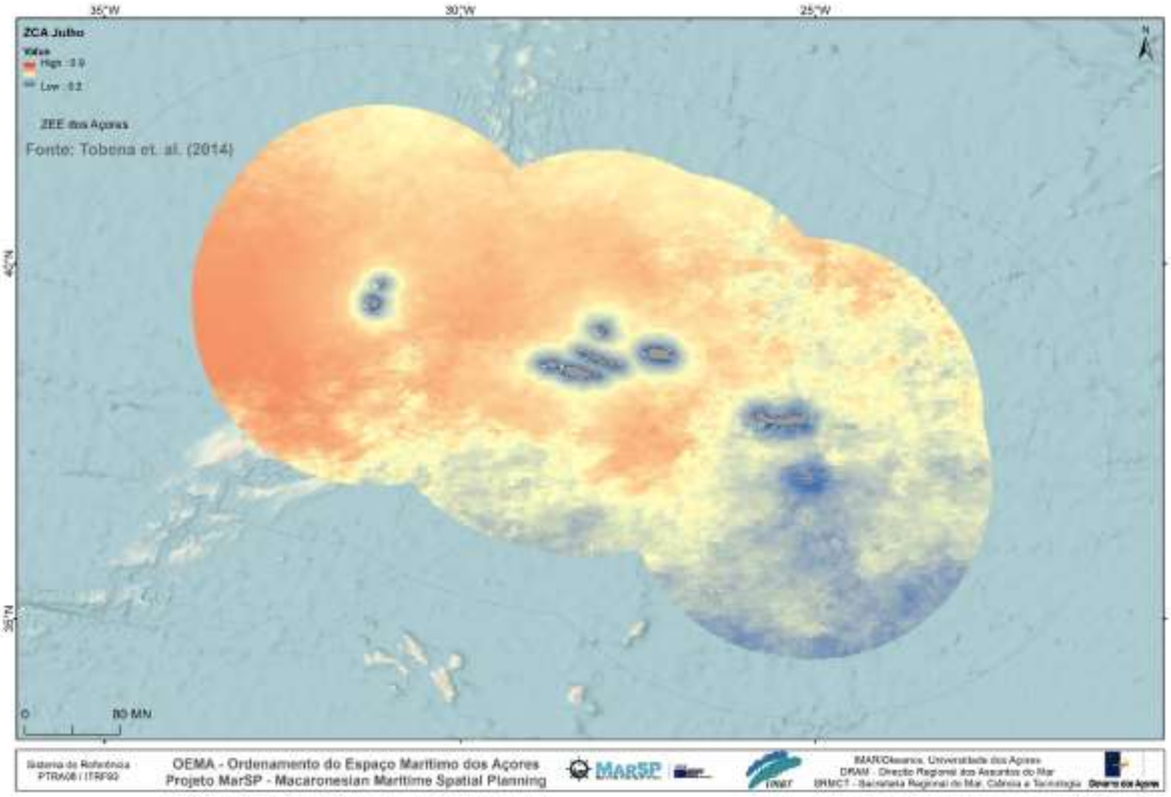
Spatial distribution of *Ziphius cavirostris* (ZCA), May



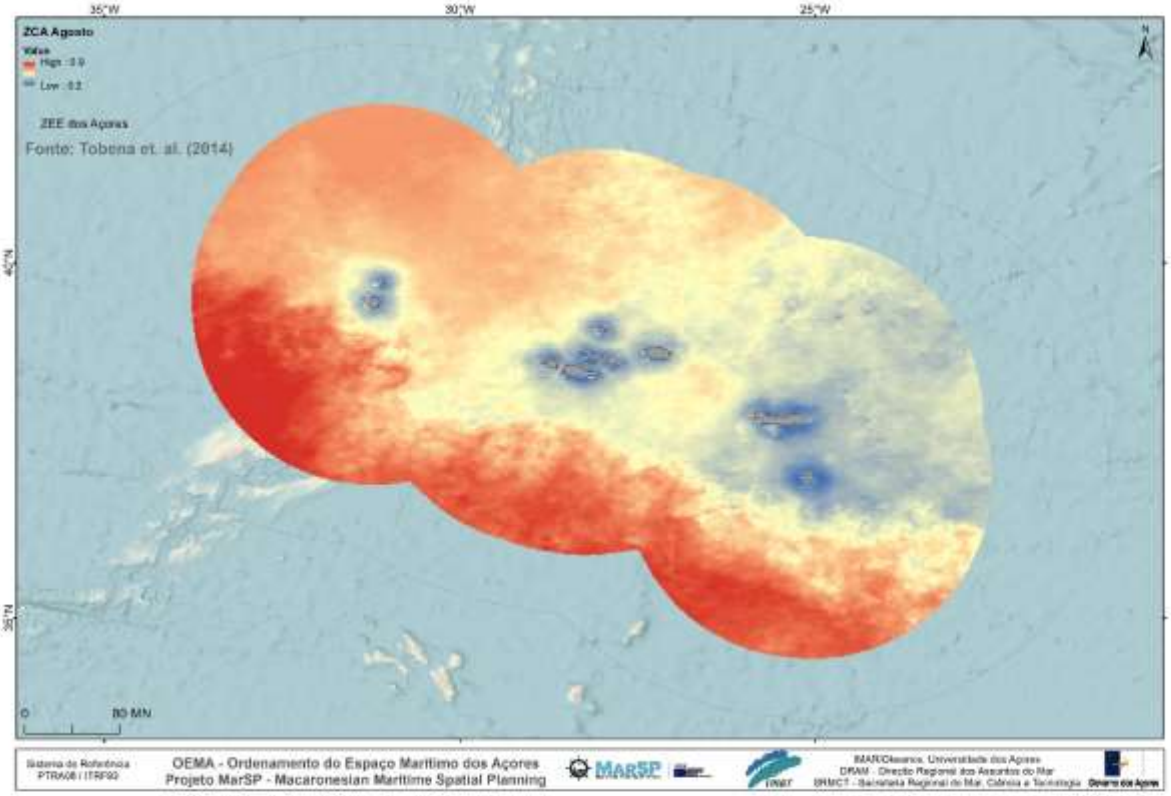
Spatial distribution of *Ziphius cavirostris* (ZCA), June



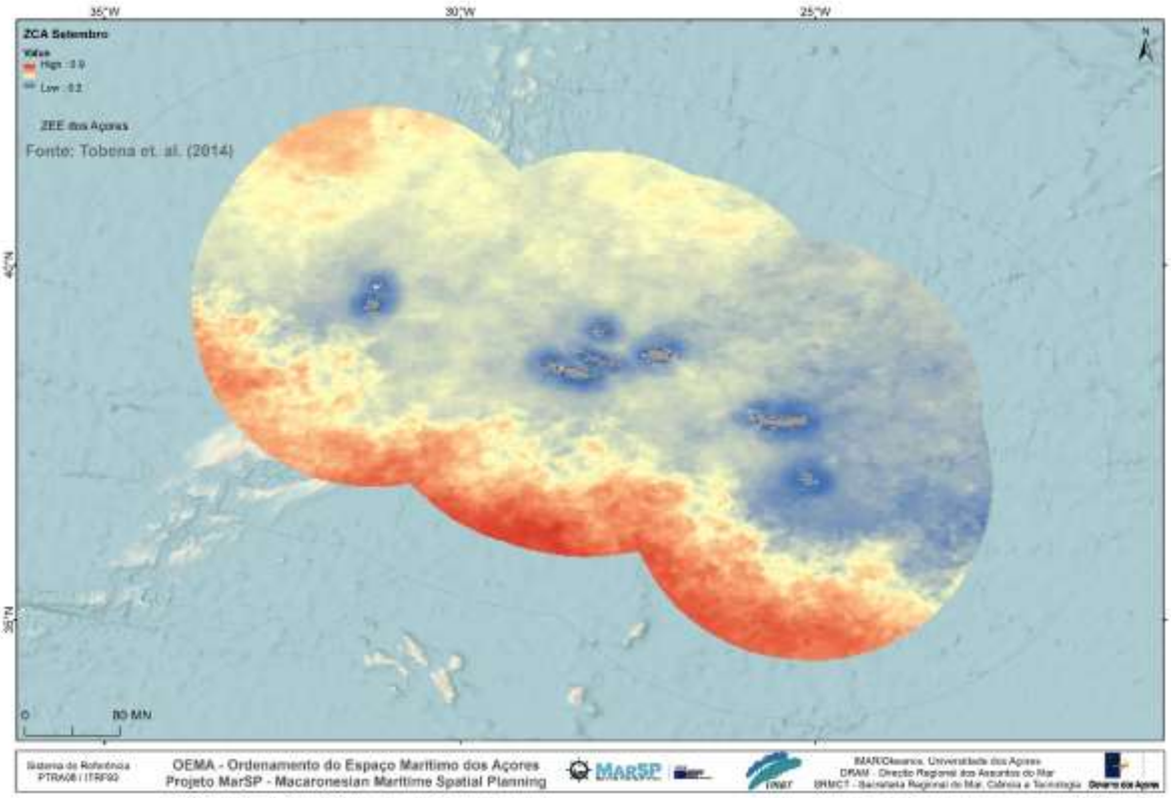
Spatial distribution of *Ziphius cavirostris* (ZCA), July



Spatial distribution of *Ziphius cavirostris* (ZCA), August

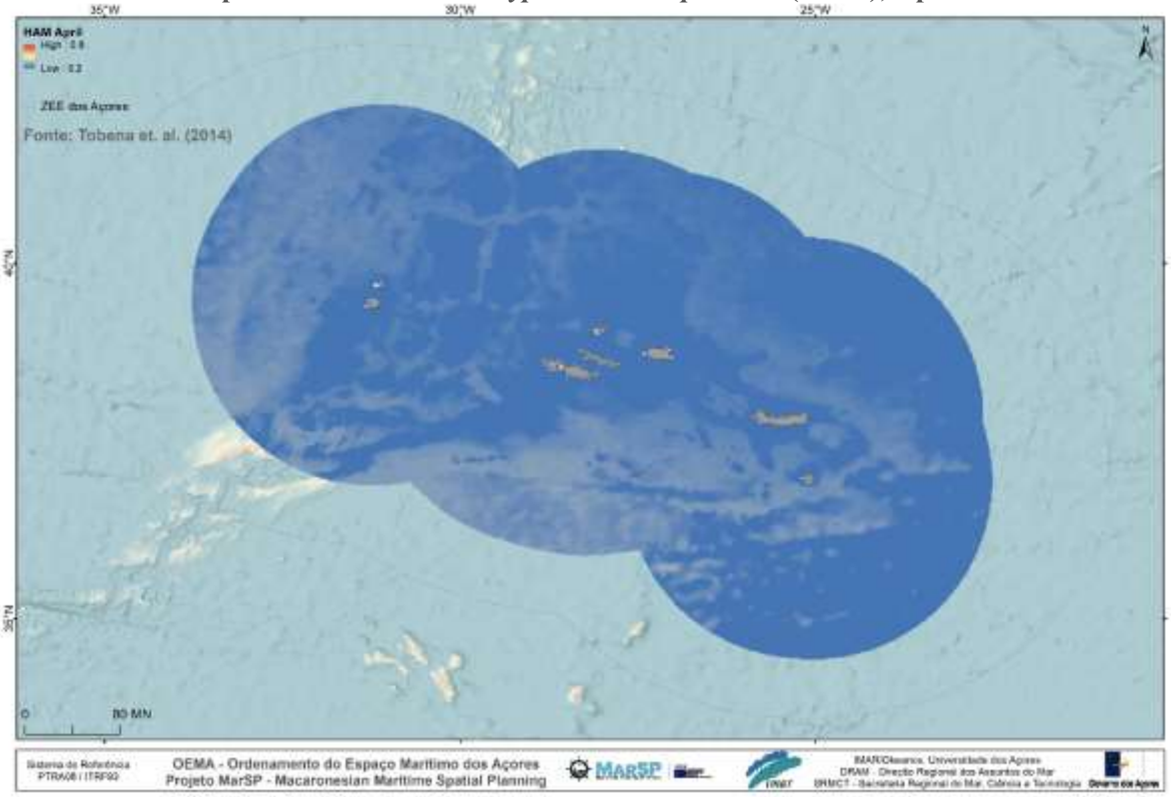


Spatial distribution of *Ziphius cavirostris* (ZCA), September

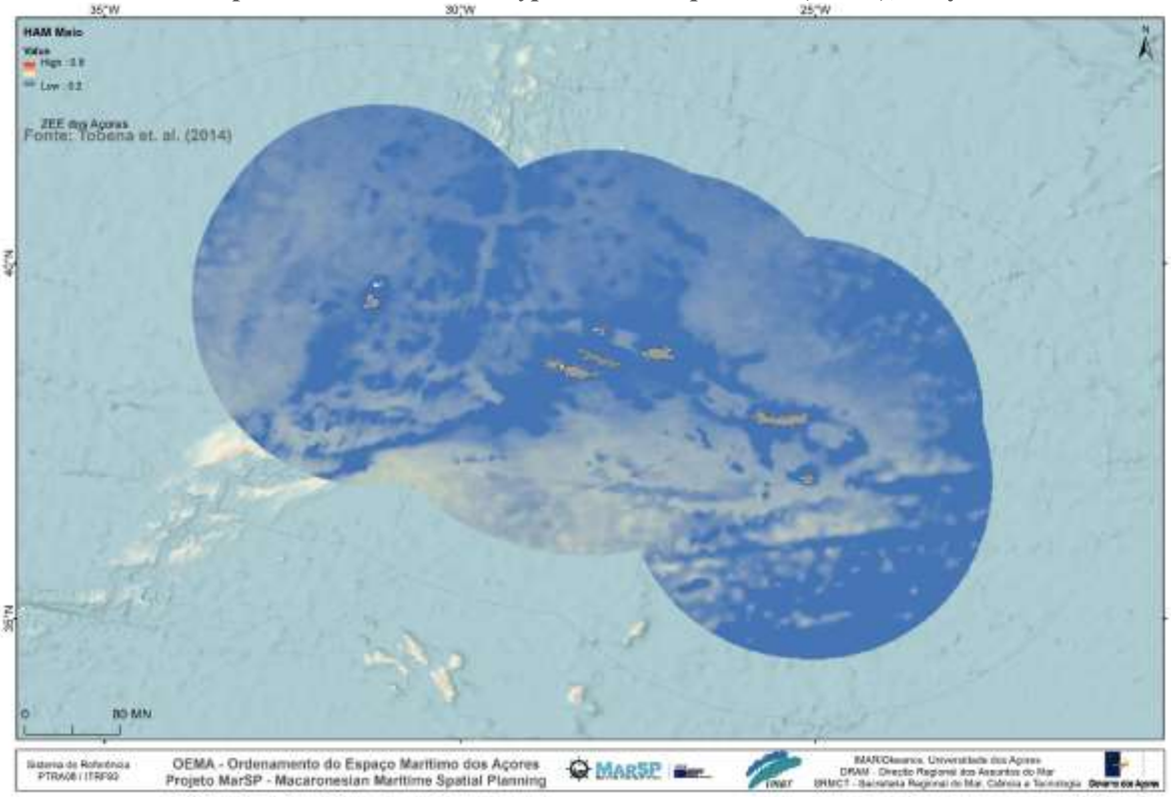


3.2.3. *Hyperoodon ampullatus* (from April to September) – 6 models

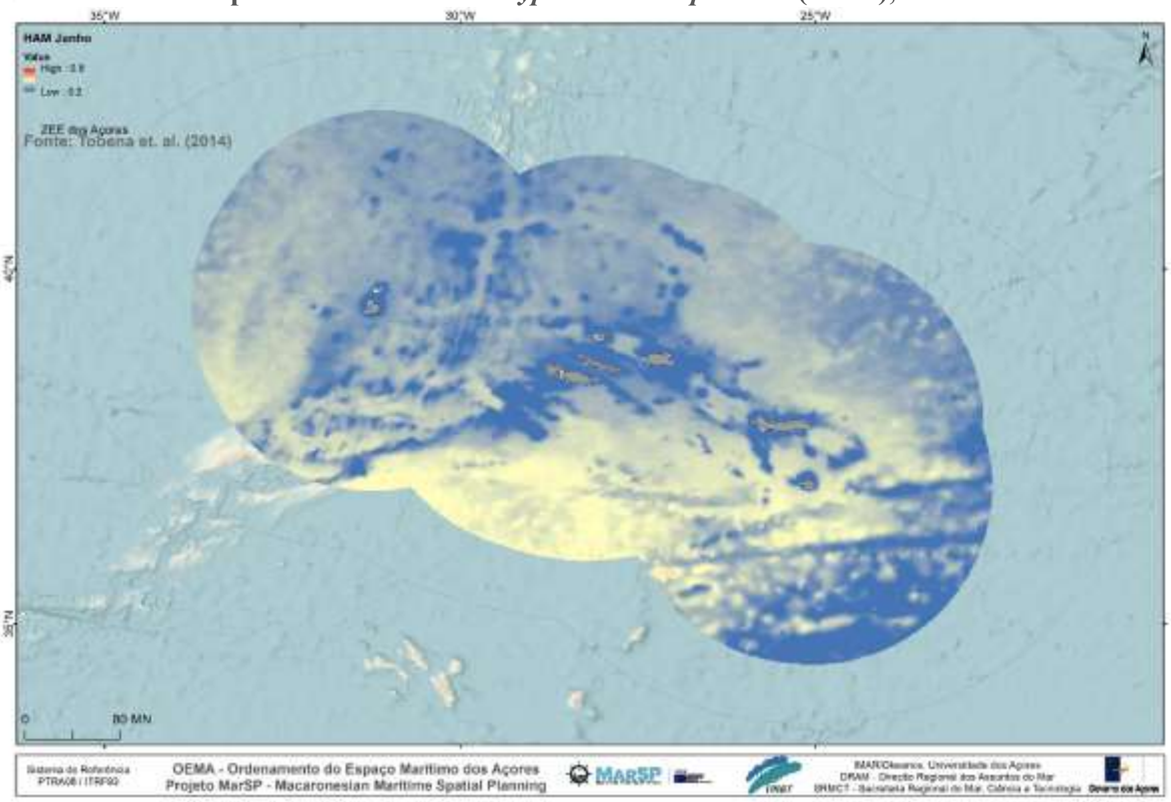
Spatial distribution of *Hyperoodon ampullatus* (HAM), April



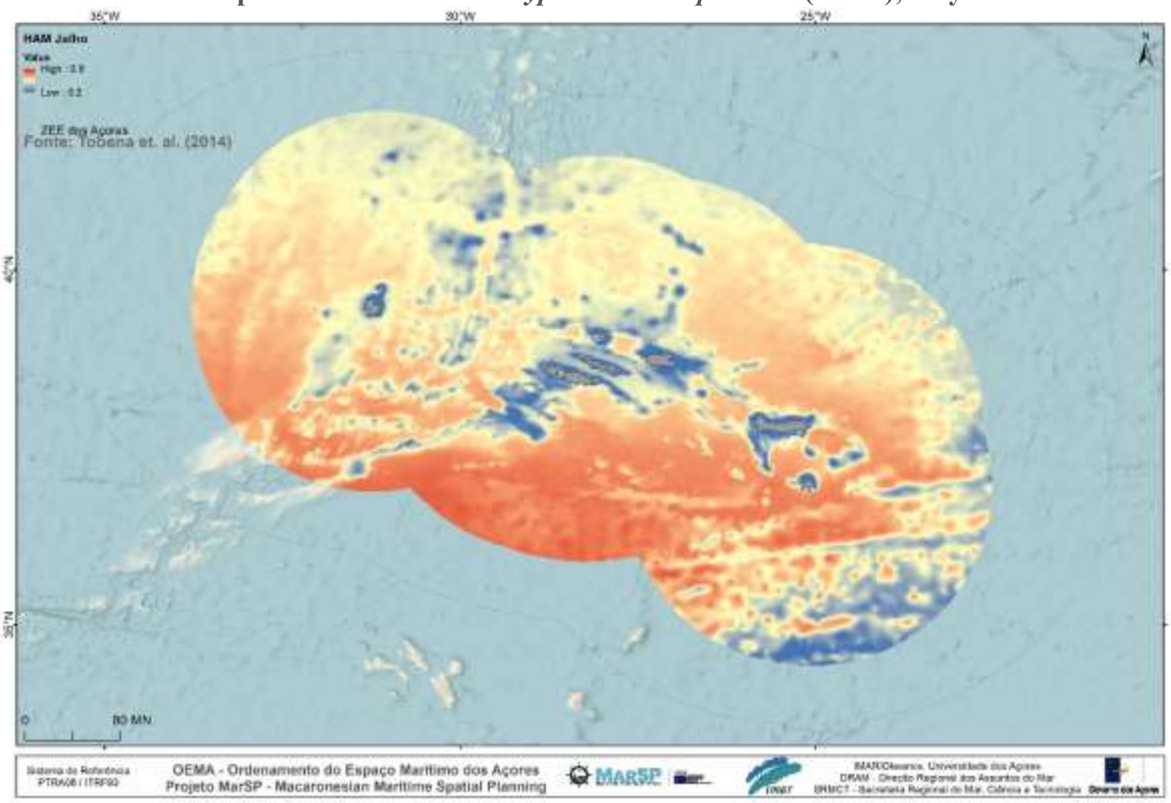
Spatial distribution of *Hyperoodon ampullatus* (HAM), May



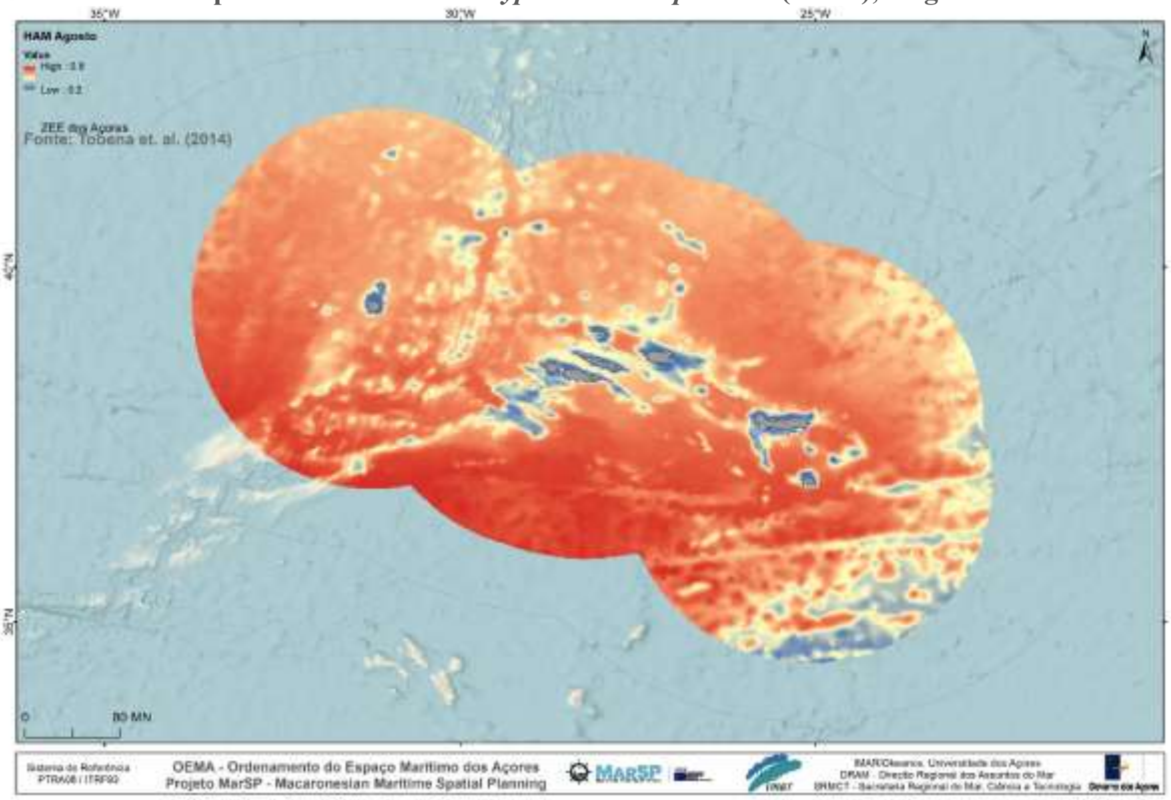
Spatial distribution of *Hyperoodon ampullatus* (HAM), June



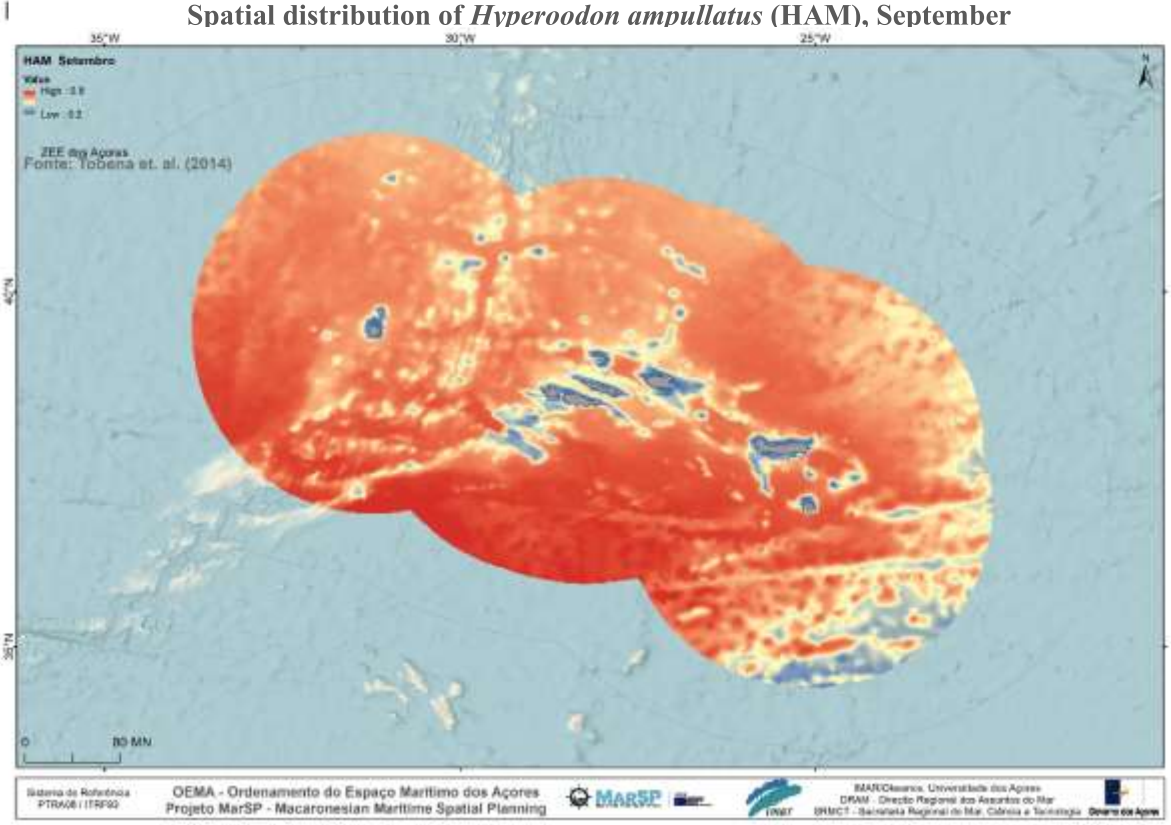
Spatial distribution of *Hyperoodon ampullatus* (HAM), July



Spatial distribution of *Hyperoodon ampullatus* (HAM), August

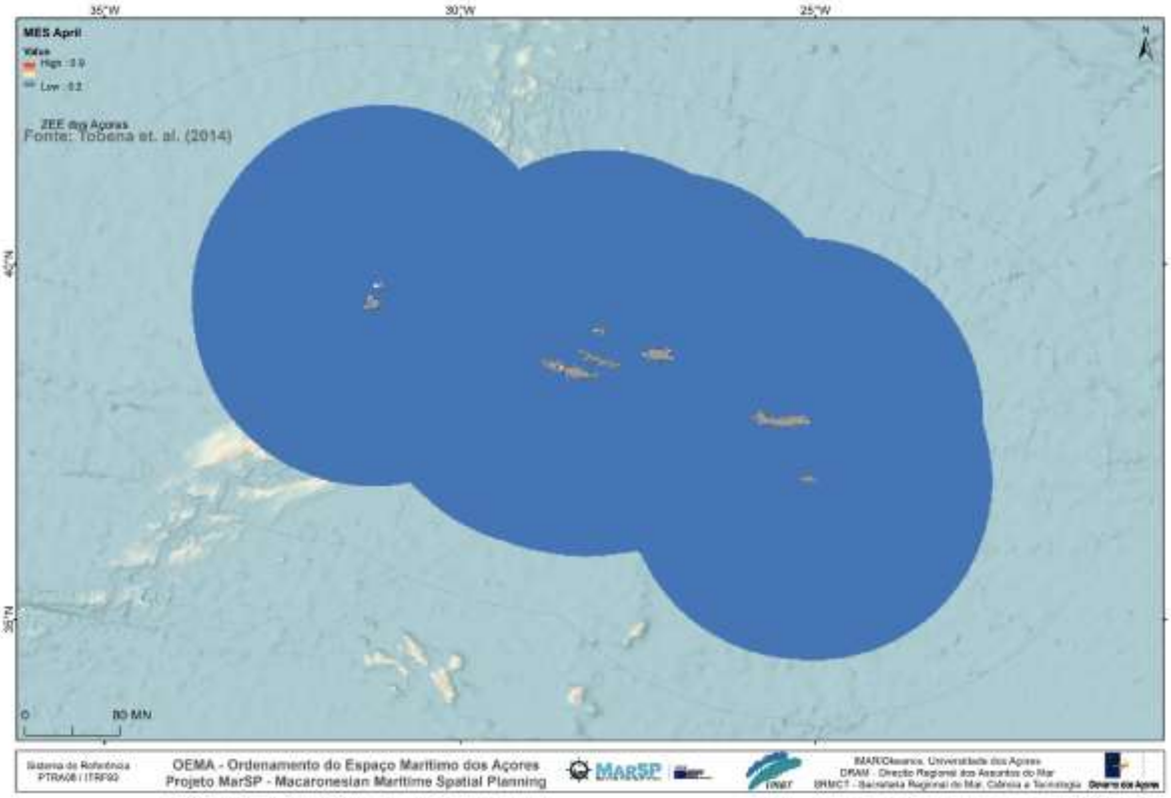


Spatial distribution of *Hyperoodon ampullatus* (HAM), September

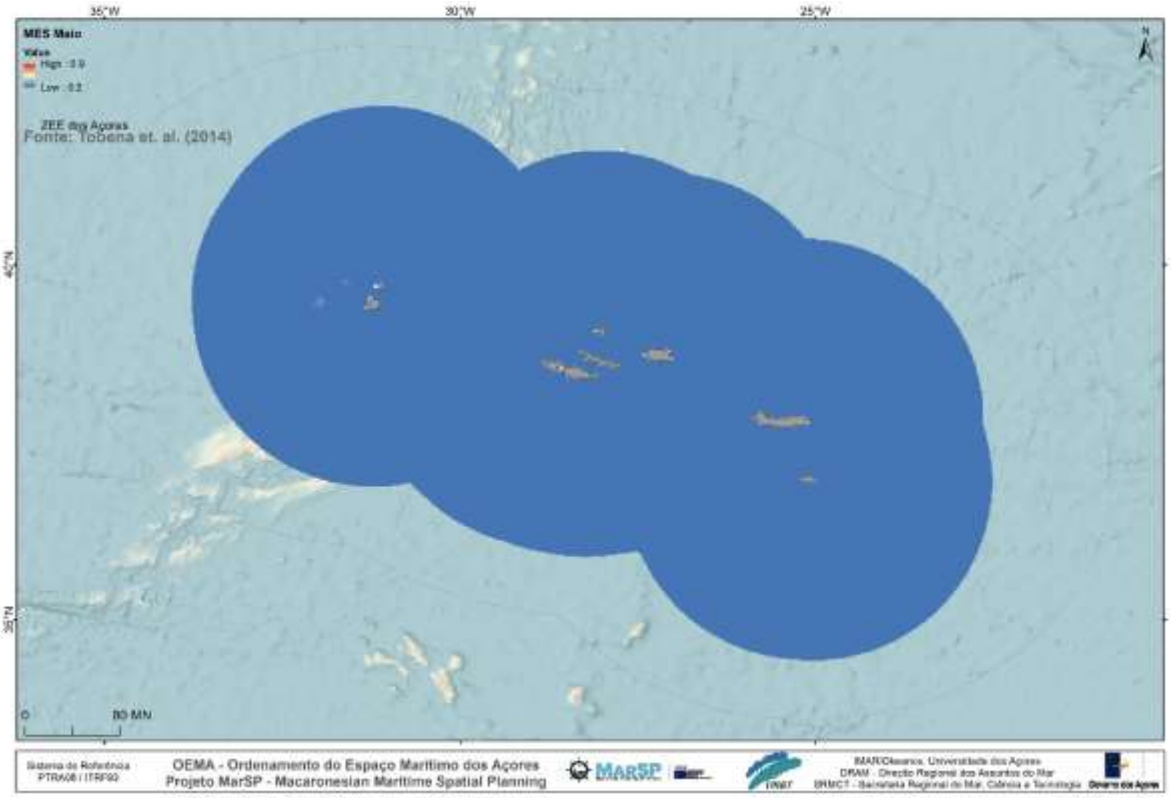


3.2.4. *Mesoplodon* spp. (from April to September) – 6 models

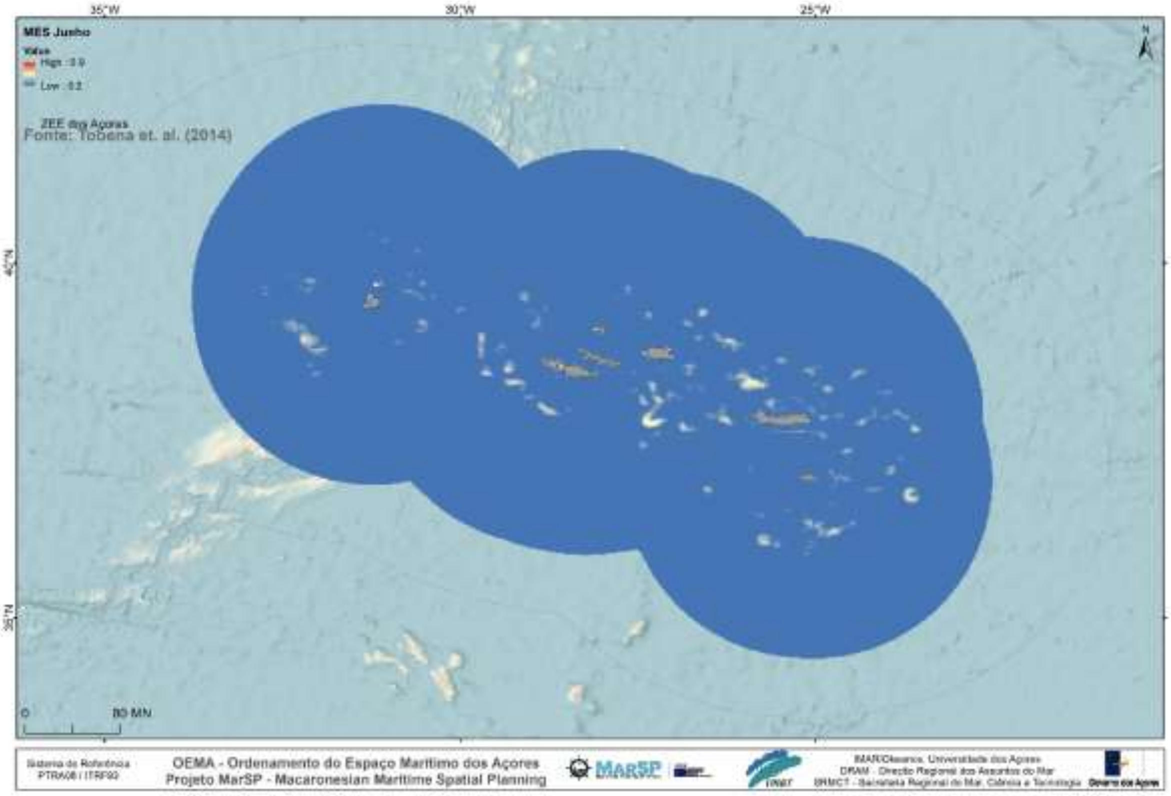
Spatial distribution of *Mesoplodon* spp. (MES), April



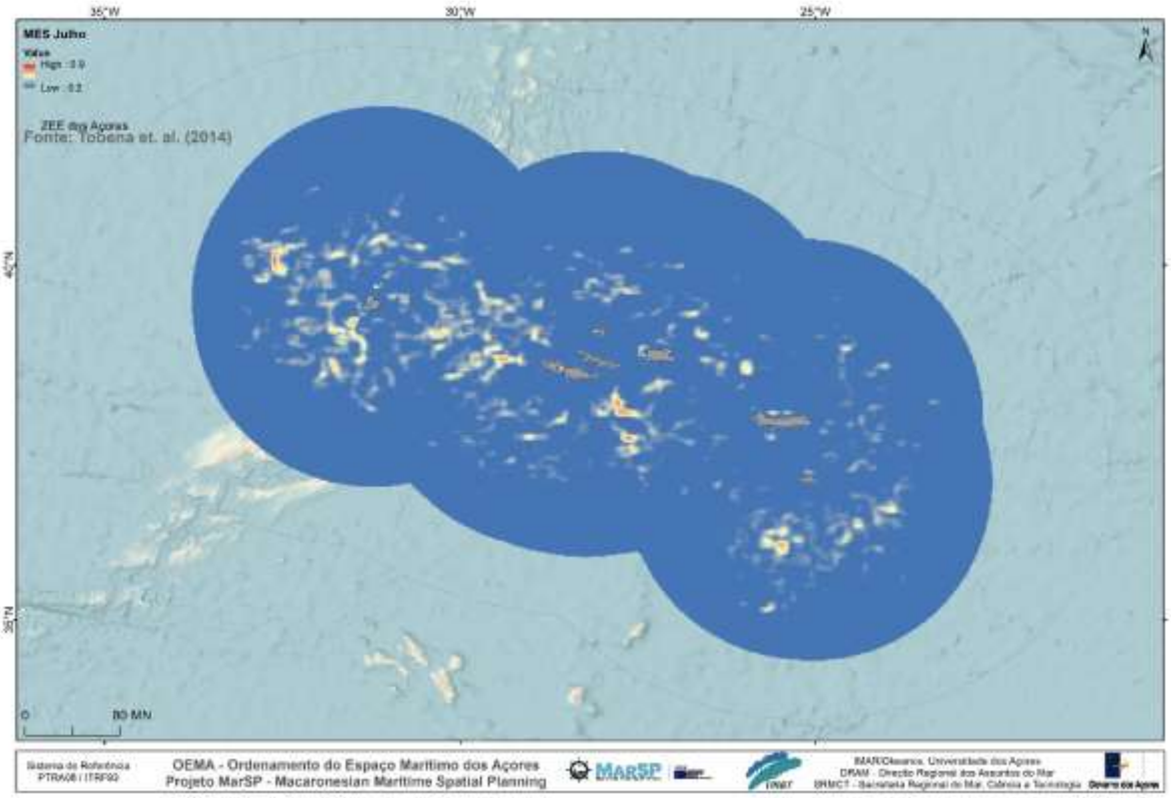
Spatial distribution of *Mesoplodon* spp. (MES), May



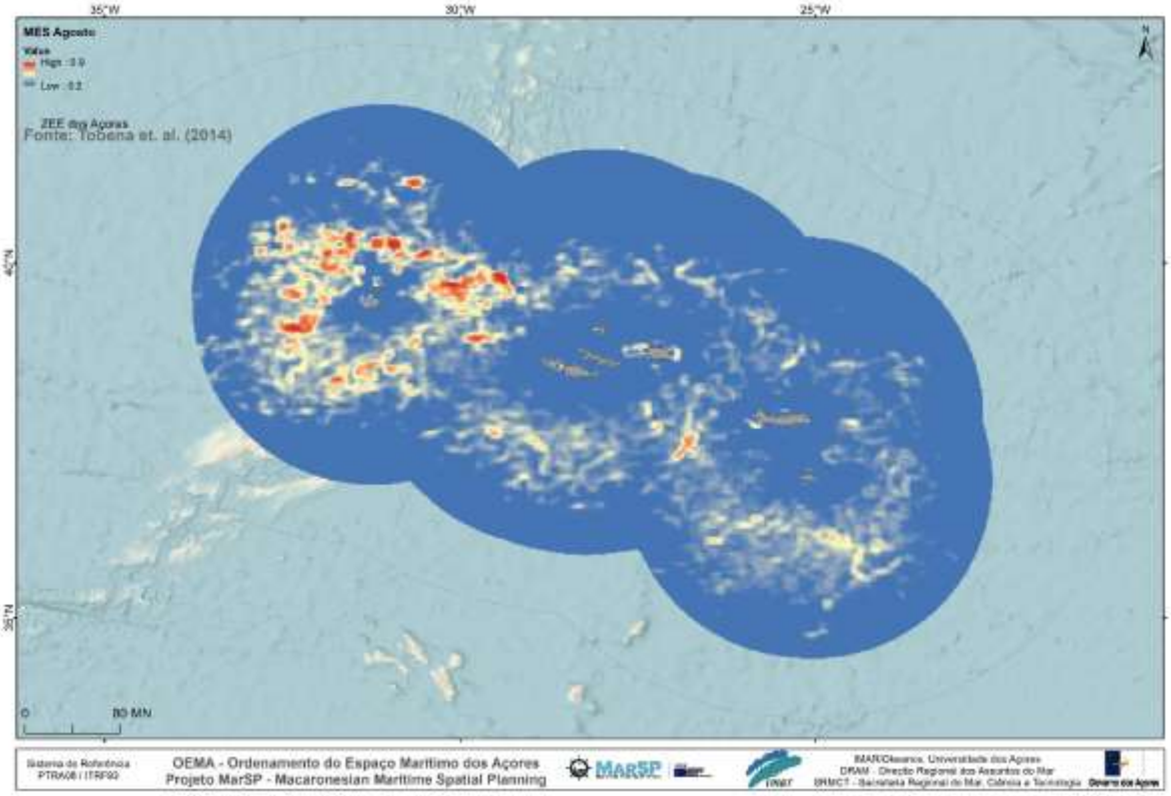
Spatial distribution of *Mesoplodon* spp. (MES), June



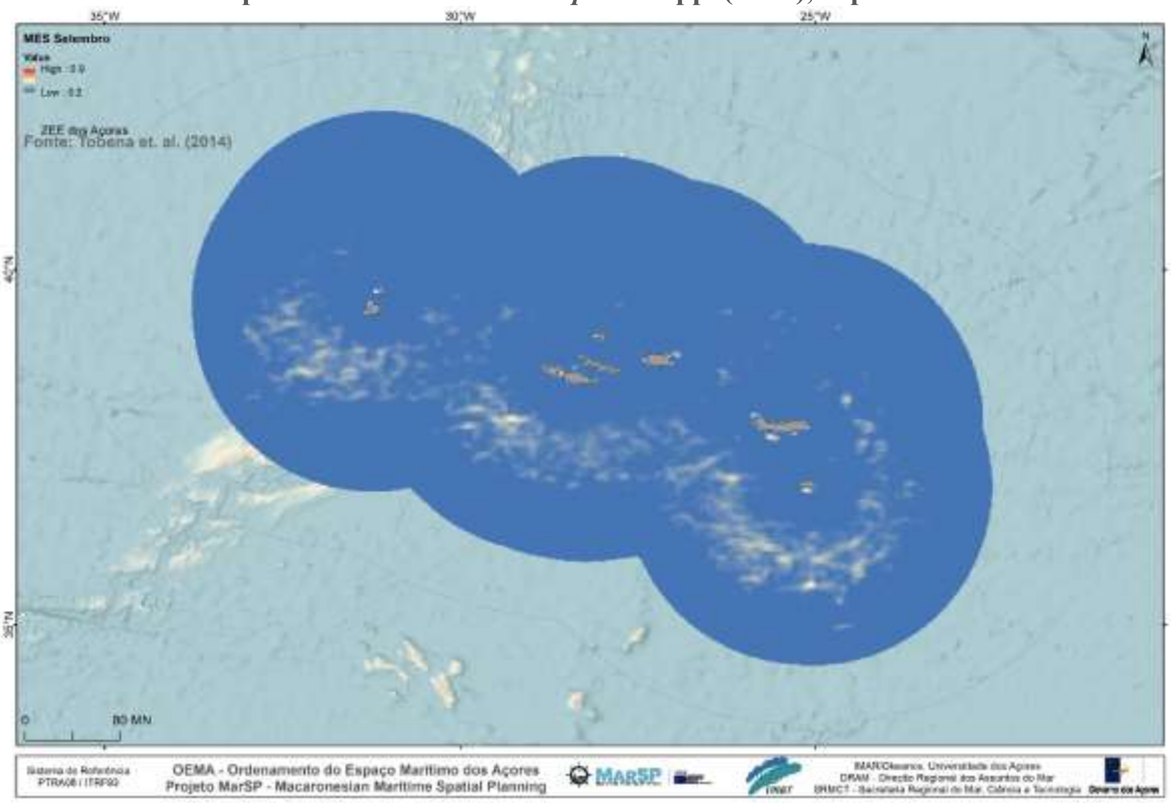
Spatial distribution of *Mesoplodon* spp. (MES), July



Spatial distribution of *Mesoplodon* spp. (MES), August



Spatial distribution of *Mesoplodon* spp. (MES), September



3.3. Cetaceans / Small dolphins

Raster Dataset Series (24 models): 1704m (1,21Mb)

- *Tursiops truncatus* (from April to September) – 6 models
- *Stenella frontalis* (from April to September) – 6 models
- *Stenella coeruleoalba* (from April to September) – 6 models
- *Delphinus delphis* (from April to September) – 6 models

Year: 2014

Keywords: cetacean, spatio-temporal distribution, Azores, delphinids, species distribution models (SDMs), richness, MaxEnt

Summary: Mapped small delphinids habitat suitability and richness in the Azores.

Description: Marine spatial planning and ecological research call for high-resolution species distribution data. However, those data are still not available for most marine large vertebrates. The dynamic nature of oceanographic processes and the wide-ranging behaviour of many marine vertebrates create further difficulties, as distribution data must incorporate both the spatial and temporal dimensions. Cetaceans play an essential role in structuring and maintaining marine ecosystems and face increasing threats from human activities. The Azores holds a high diversity of cetaceans but the information about spatial and temporal patterns of distribution for this marine megafauna group in the region is still very limited. To tackle this issue, we created monthly predictive cetacean distribution maps for spring and summer months, using data collected by the Azores Fisheries Observer Programme between 2004 and 2009. We then combined the individual predictive maps to obtain species richness maps for the same period. Our results reflect a great heterogeneity in distribution among species and within species among different months. This heterogeneity reflects a contrasting influence of oceanographic processes on the distribution of cetacean species. However, some persistent areas of increased species richness could also be identified from our results. We argue that policies aimed at effectively protecting cetaceans and their habitats must include the principle of dynamic ocean management coupled with other area-based management such as marine spatial planning. This work was supported by FEDER funds, through the Competitiveness Factors Operational Programme - COMPETE, by national funds, through FCT - Foundation for Science and Technology, under project TRACE (PTDC/ MAR/74071/2006), and by regional funds, through DRCT/SRCTE, under projects MAPCET (M2.1.2/F/012/2011) and 2020 (M2.1.2/I/026/2011). We acknowledge funds provided by FCT to MARE, through the strategic project UID/MAR/04292/2013. RP is supported by an FCT postdoctoral grant (SFRH/BPD/108007/2015); MAS is supported by Program Investigator FCT (IF/00943/2013) and MT was supported by a research fellowship under the Exploratory project (IF/00943/2013/CP1199/CT0001) that also paid the fees for this open-access publication. IF/00943/2013 and IF/00943/2013/CP1199/CT0001 are funded by FSE and MCTES, through POPH and QREN.

Credits: IMAR, Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-33.775034	East	-22.508365
North	42.225002	South	34.425000

Citation Contacts:
INDIVIDUAL'S NAME Rui Prieto
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS rcabprieto@gmail.com

Point of Contact: :
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
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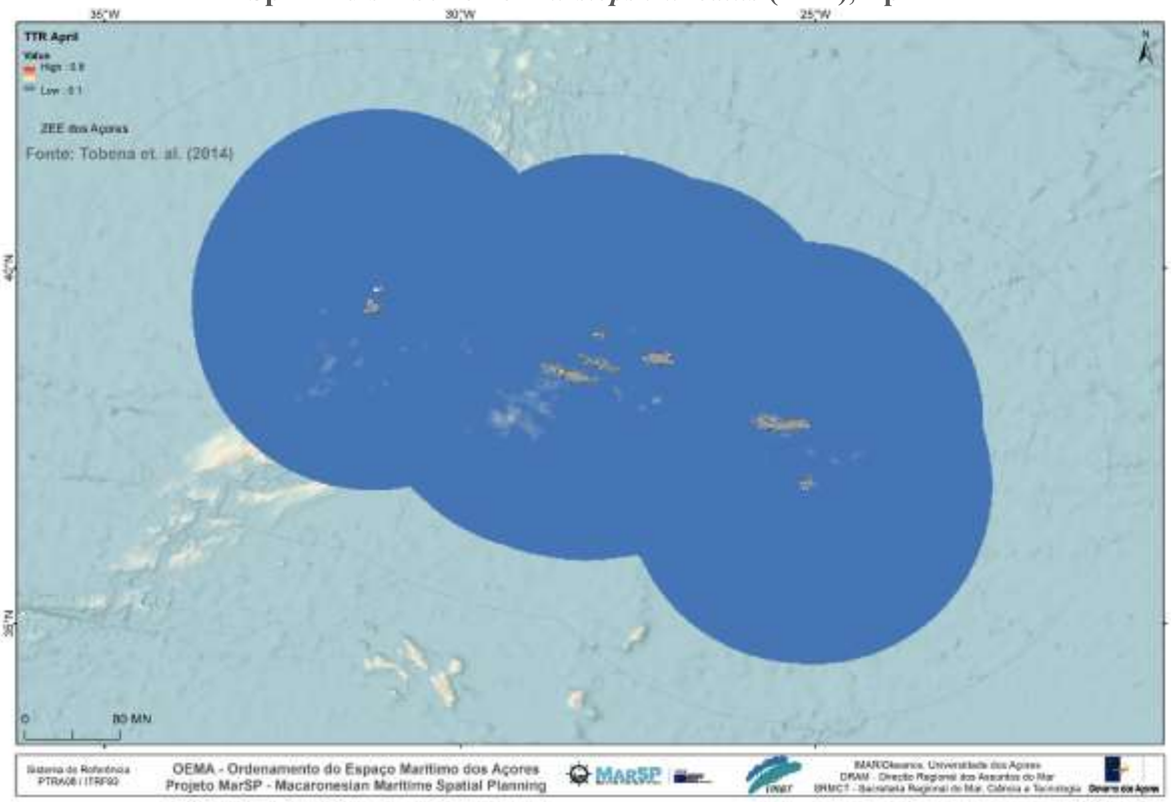
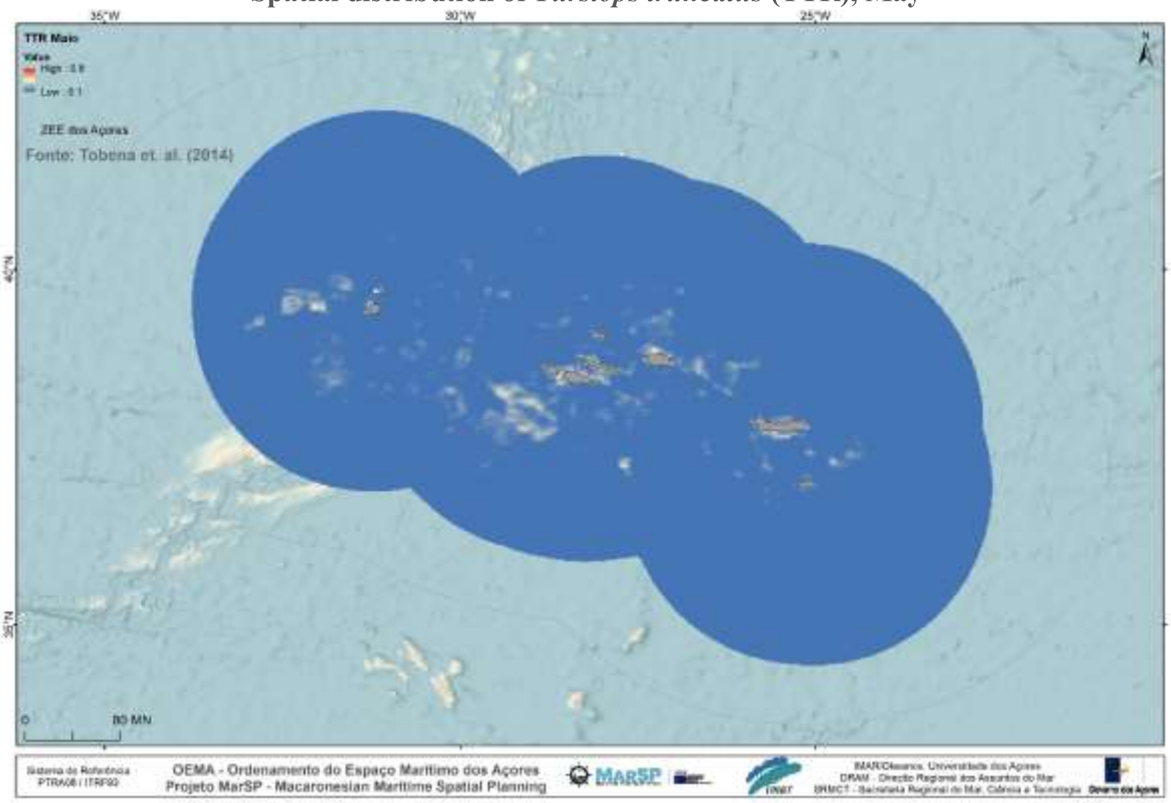
3.3.1. *Tursiops truncatus* (from April to September) – 6 models

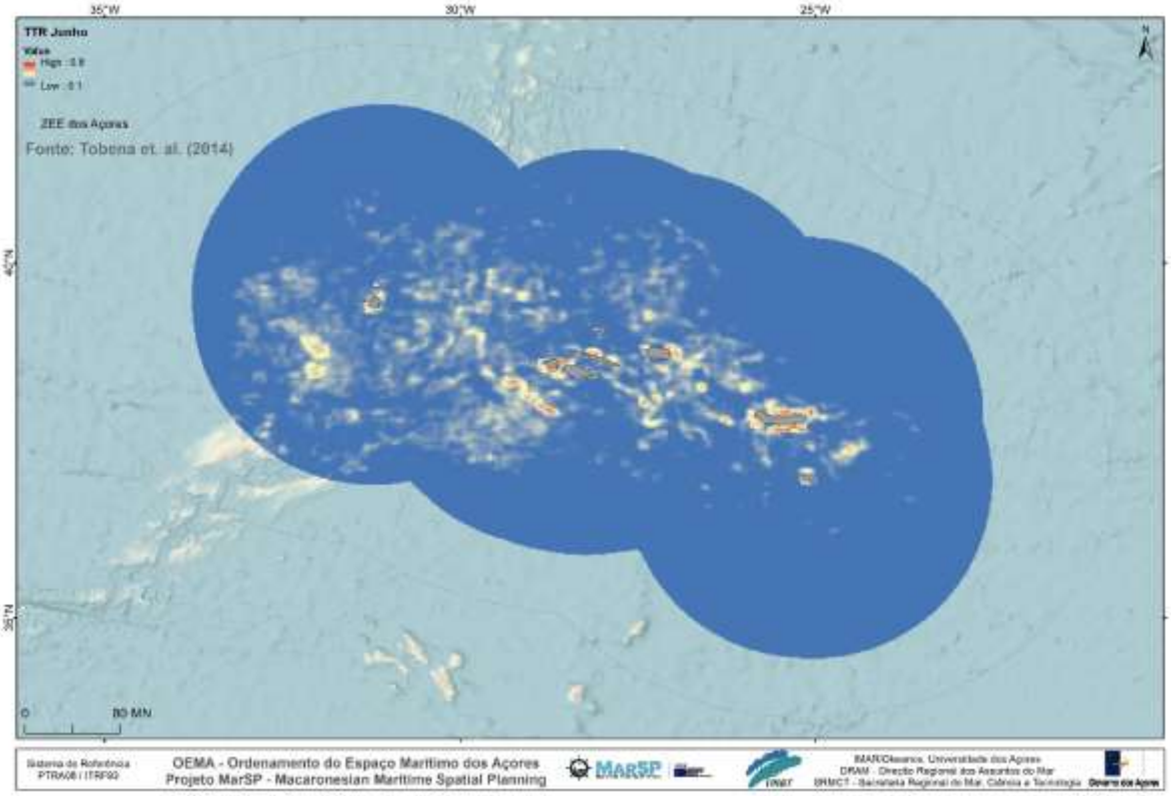
Spatial distribution of *Tursiops truncatus* (TTR), April



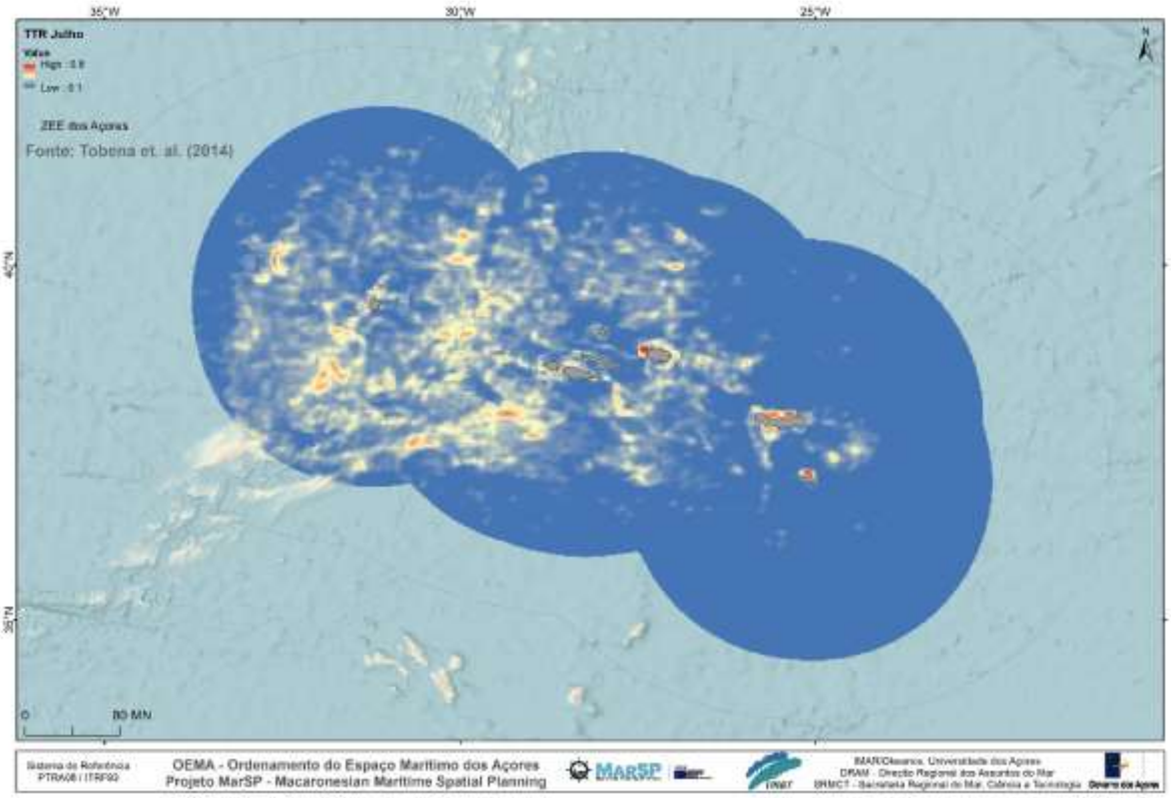
Spatial distribution of *Tursiops truncatus* (TTR), May



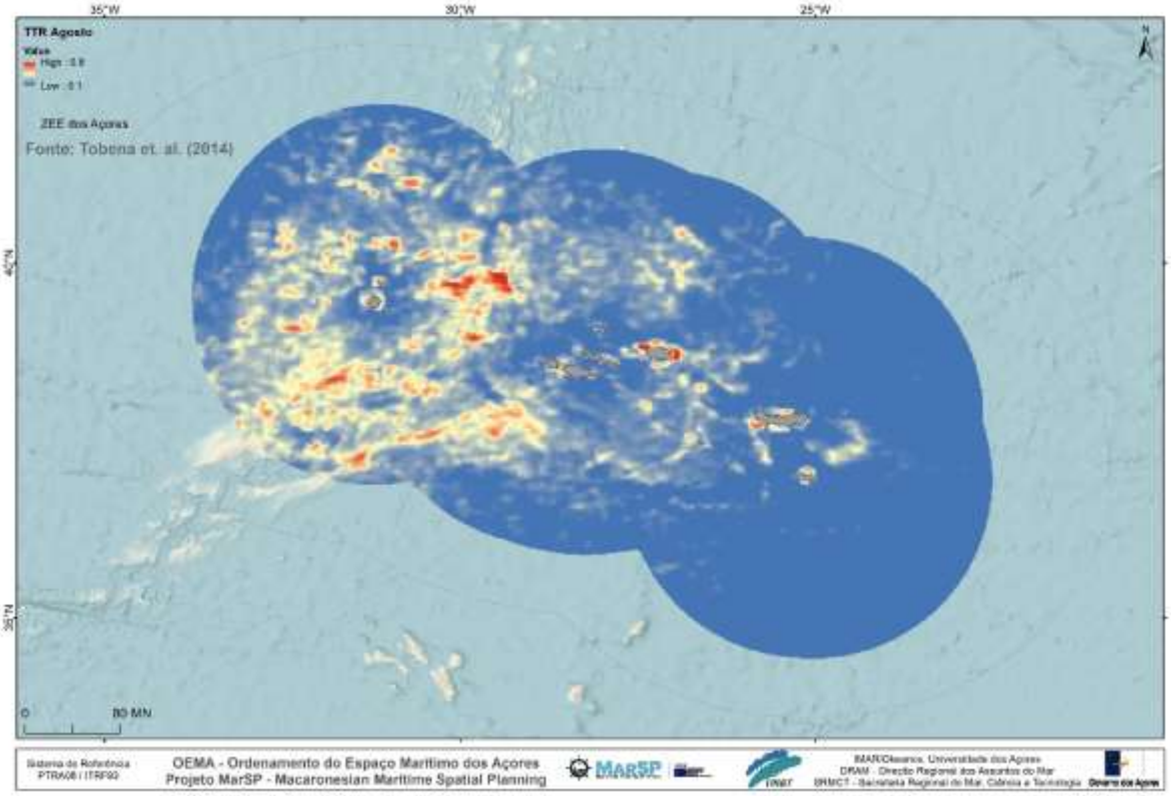
Spatial distribution of *Tursiops truncatus* (TTR), June



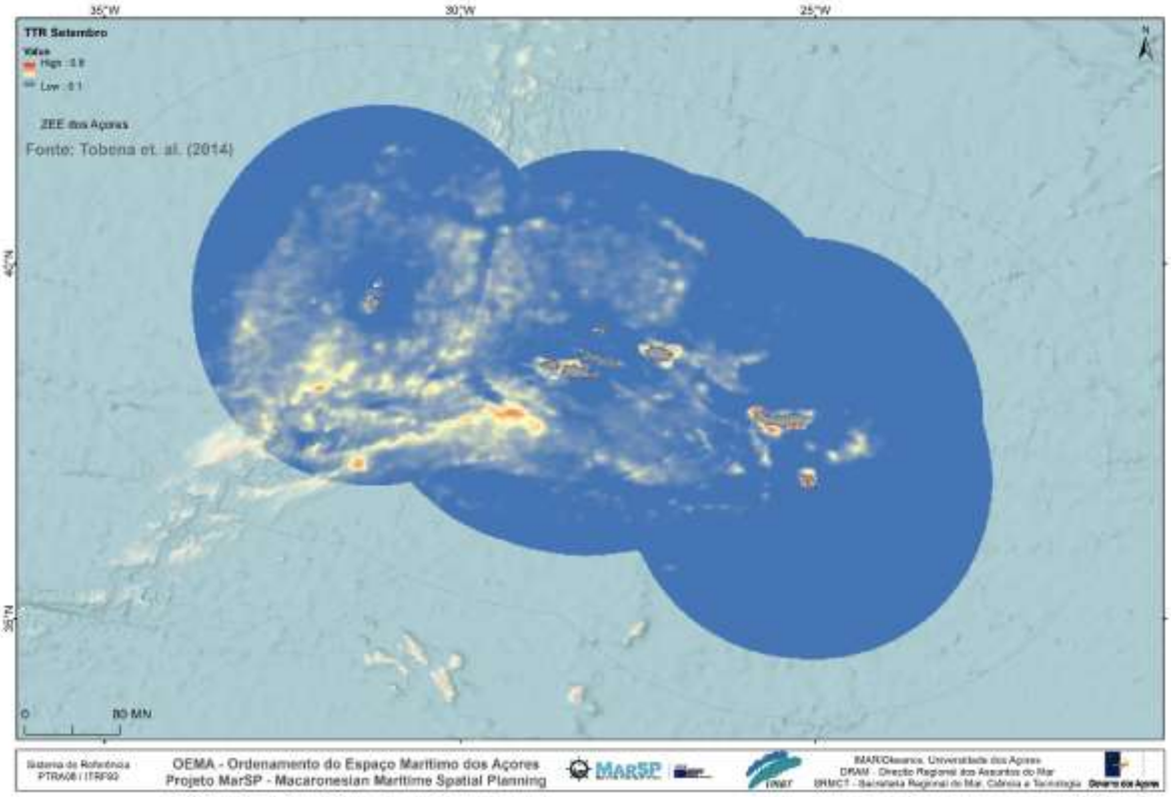
Spatial distribution of *Tursiops truncatus* (TTR), July



Spatial distribution of *Tursiops truncatus* (TTR), August

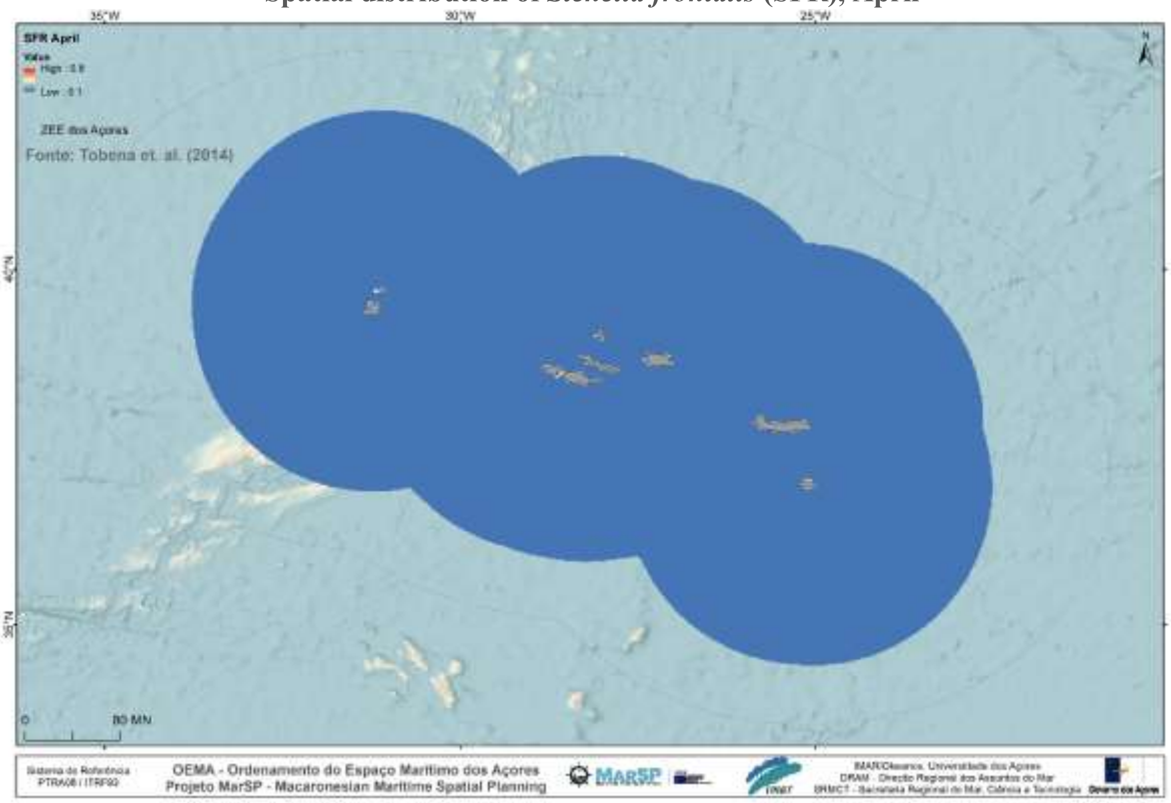


Spatial distribution of *Tursiops truncatus* (TTR), September

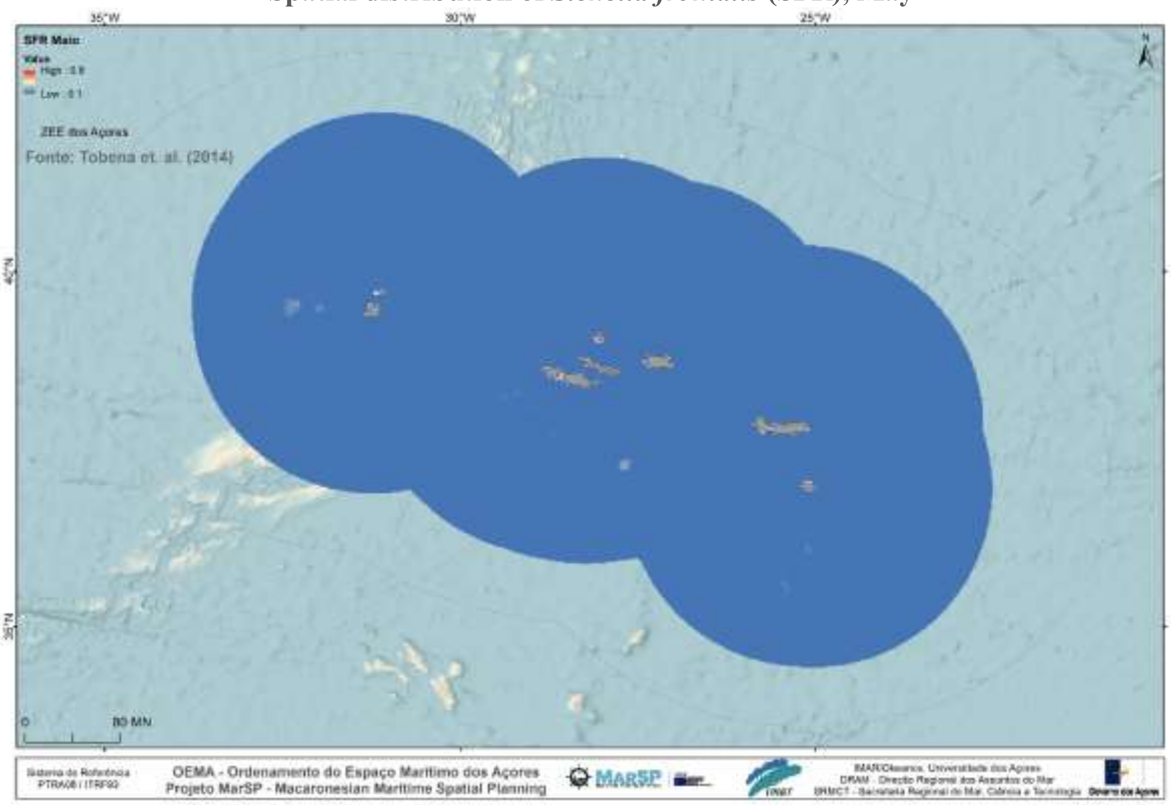


3.3.2. *Stenella frontalis* (from April to September) – 6 models

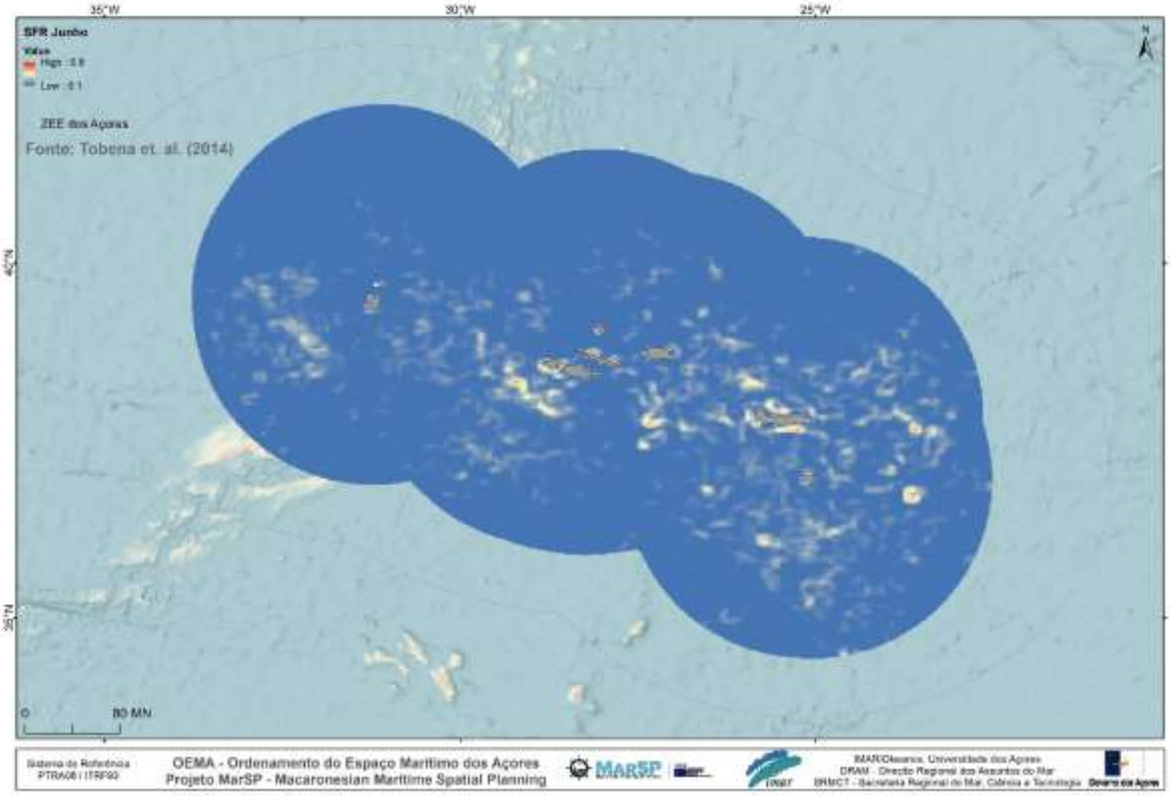
Spatial distribution of *Stenella frontalis* (SFR), April



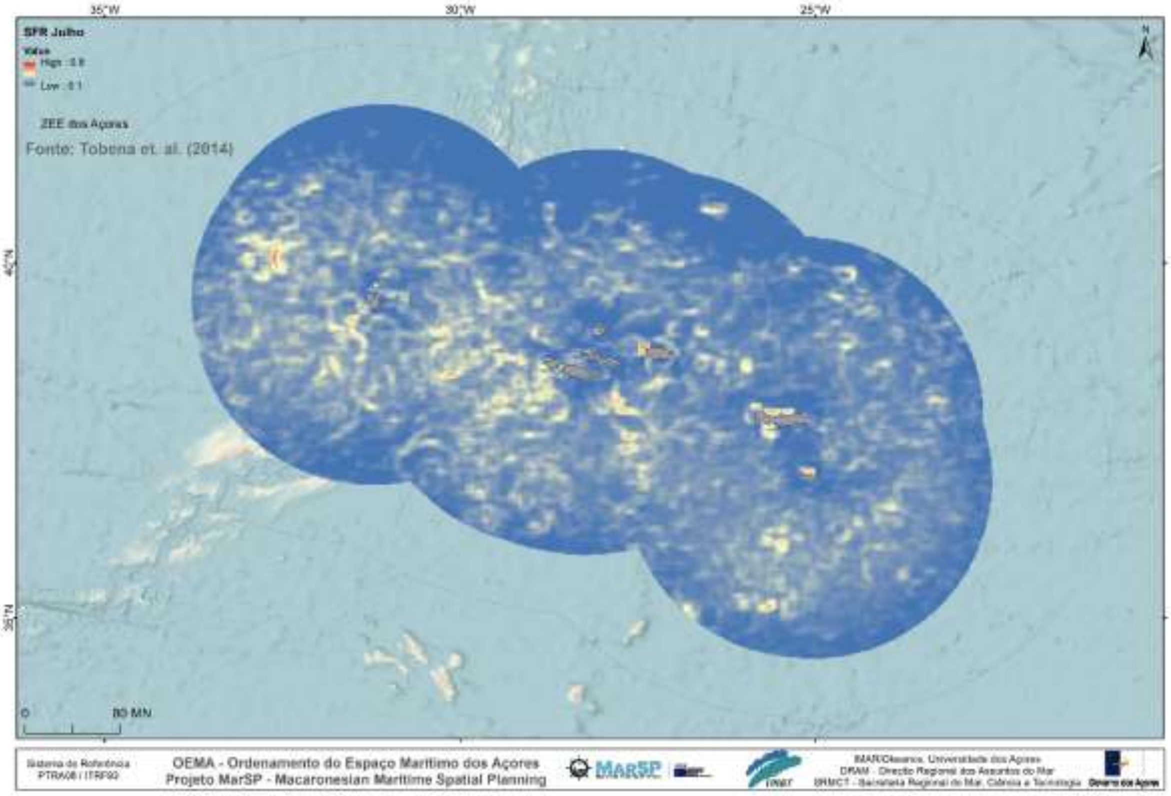
Spatial distribution of *Stenella frontalis* (SFR), May



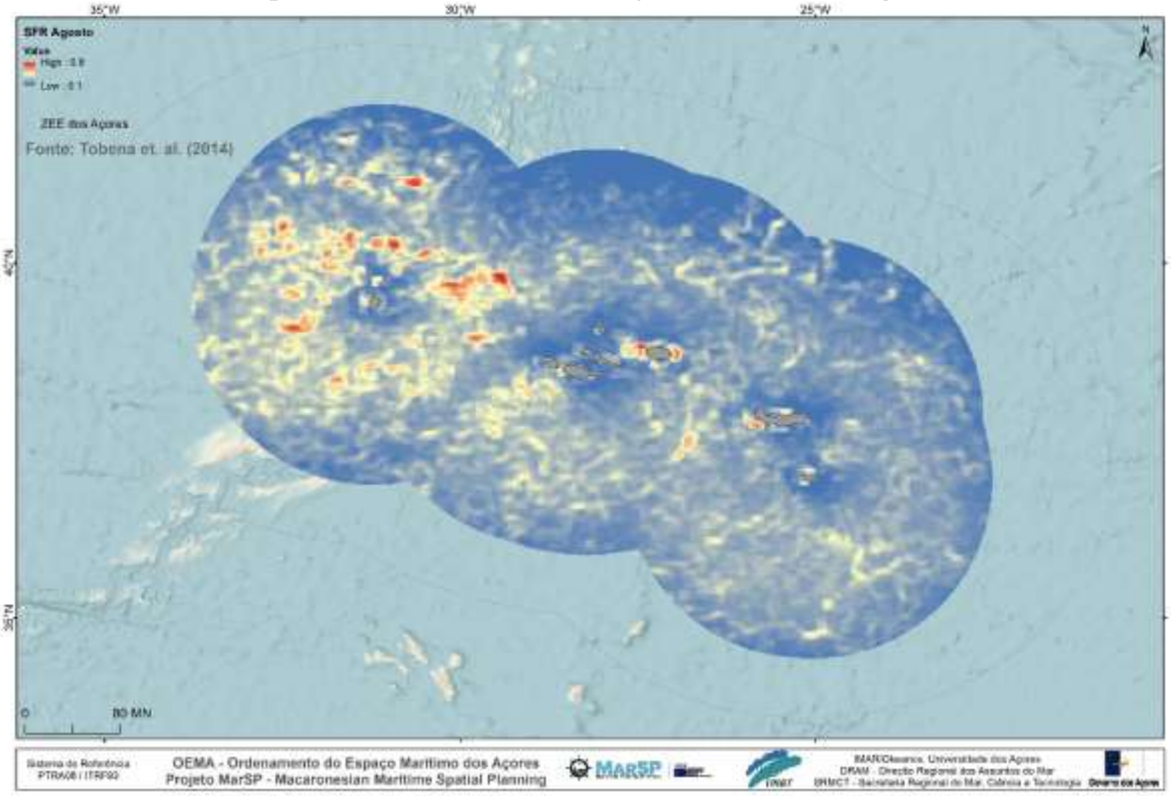
Spatial distribution of *Stenella frontalis* (SFR), June



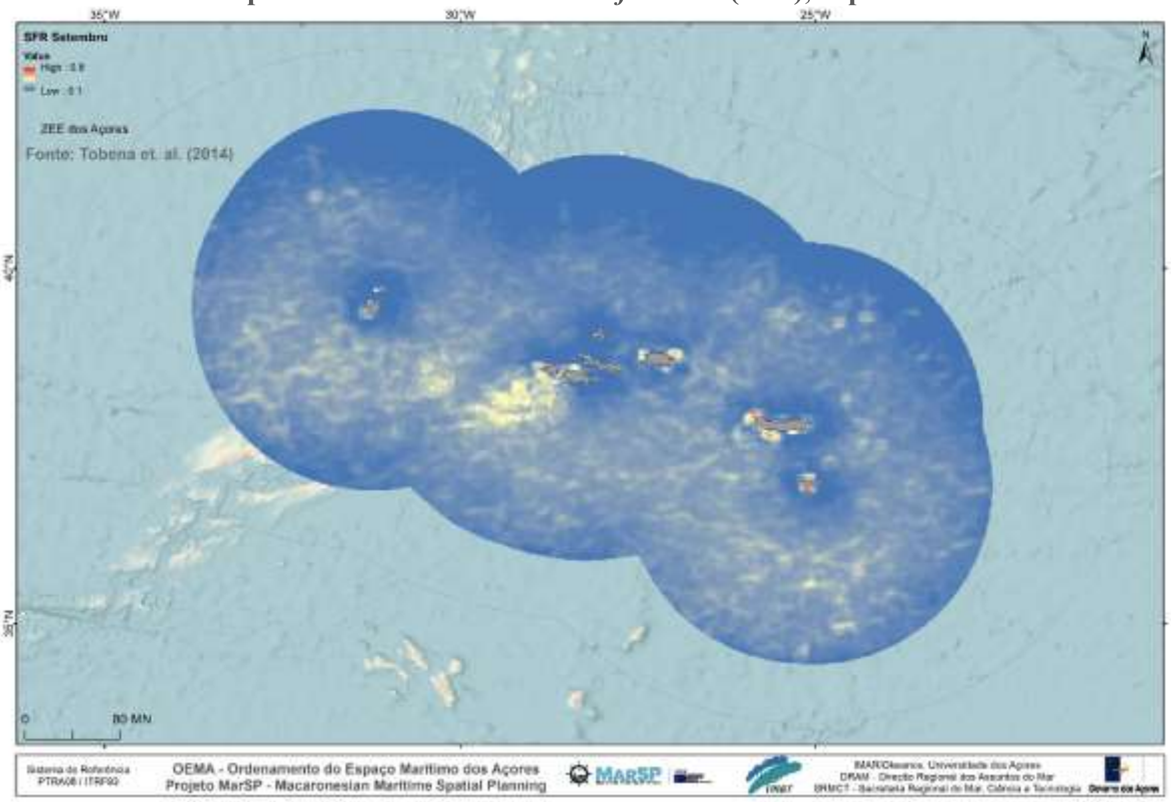
Spatial distribution of *Stenella frontalis* (SFR), July



Spatial distribution of *Stenella frontalis* (SFR), August

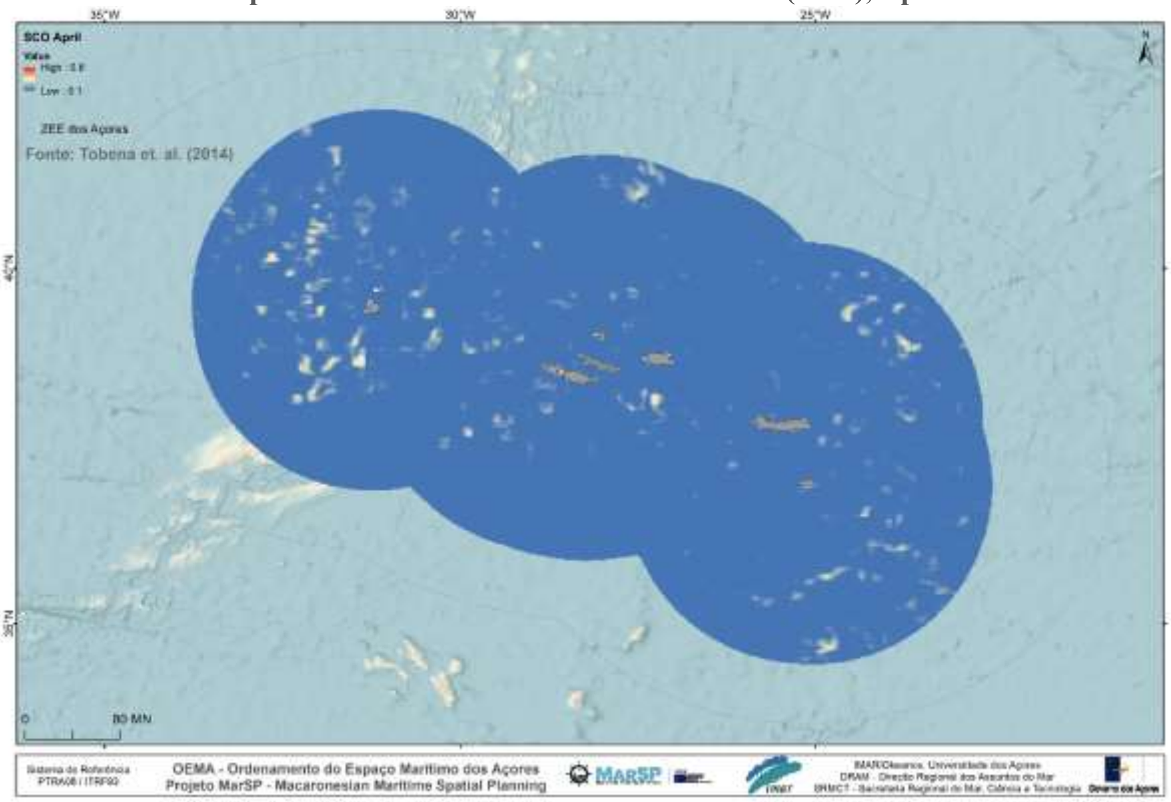


Spatial distribution of *Stenella frontalis* (SFR), September

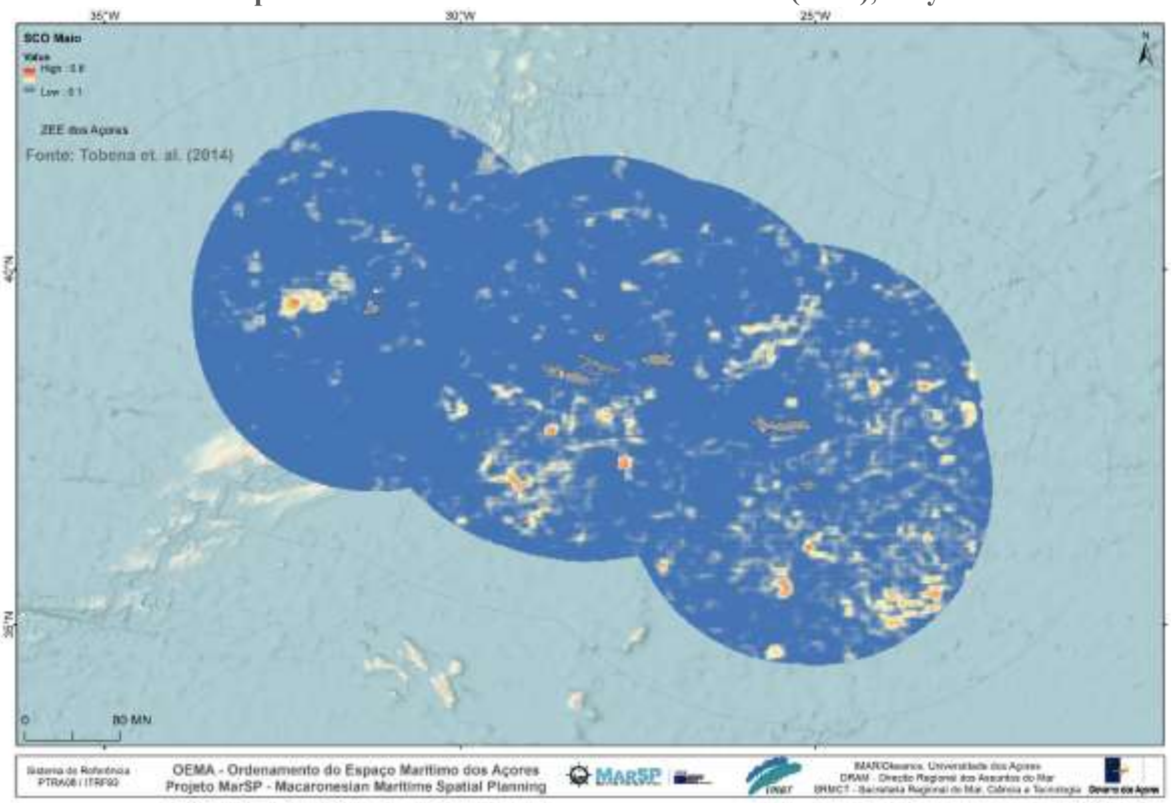


3.3.3. *Stenella coeruleoalba* (from April to September) – 6 models

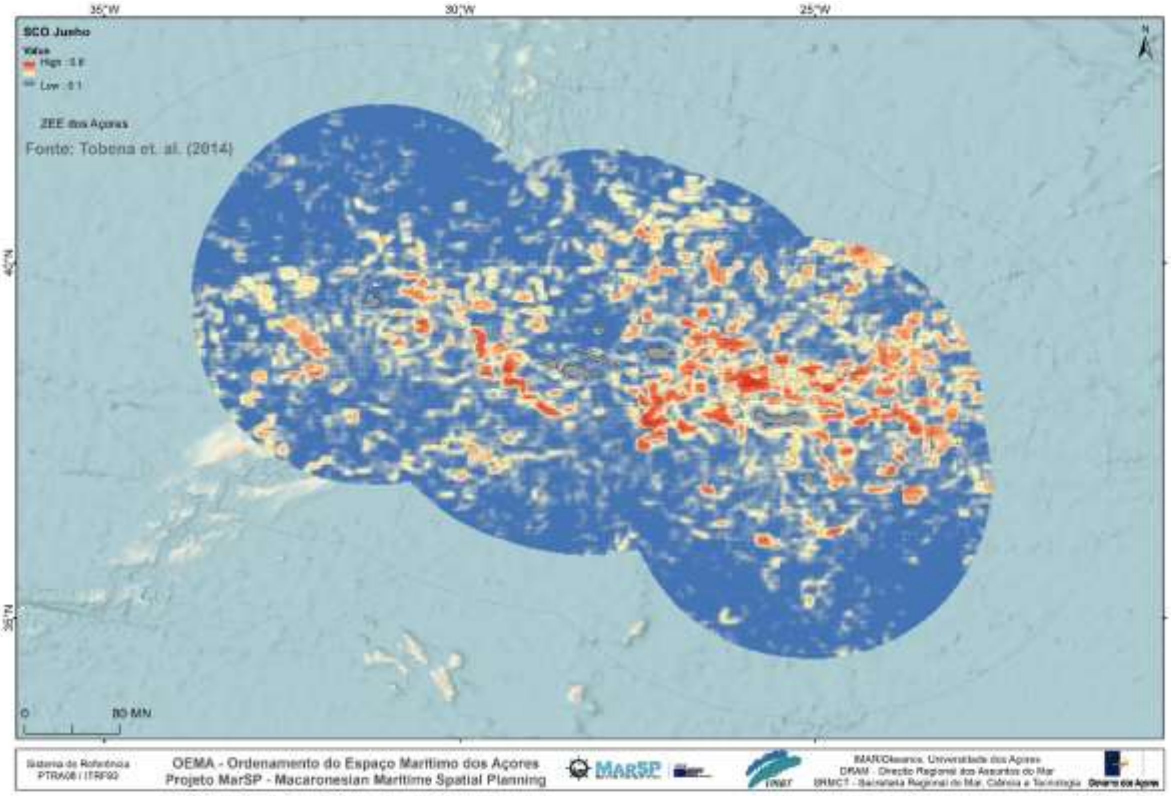
Spatial distribution of *Stenella coeruleoalba* (SCO), April



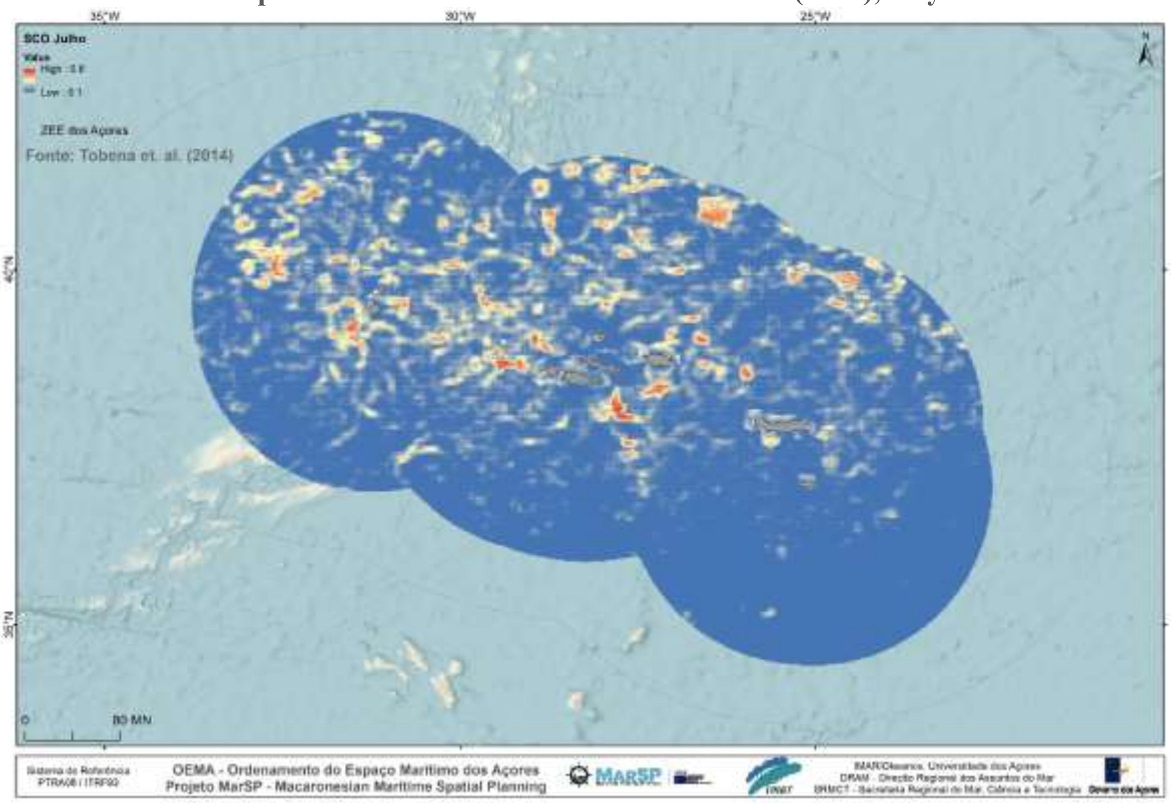
Spatial distribution of *Stenella coeruleoalba* (SCO), May



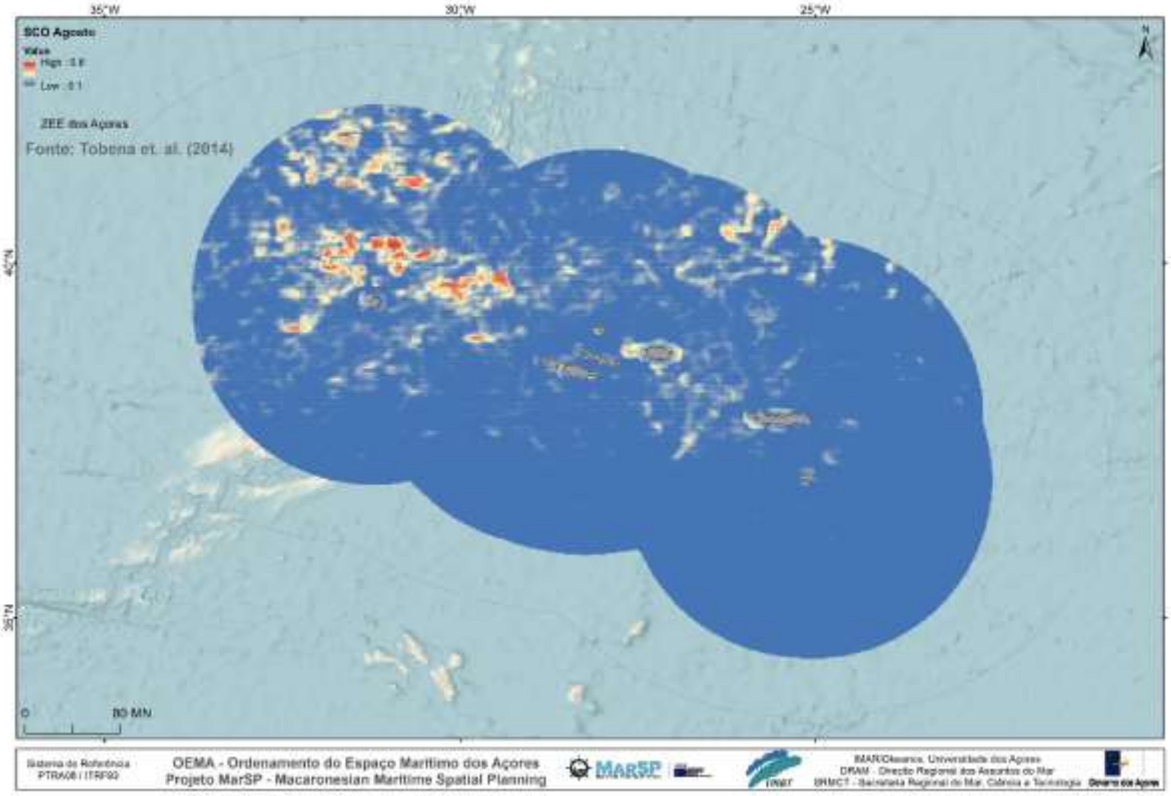
Spatial distribution of *Stenella coeruleoalba* (SCO), June



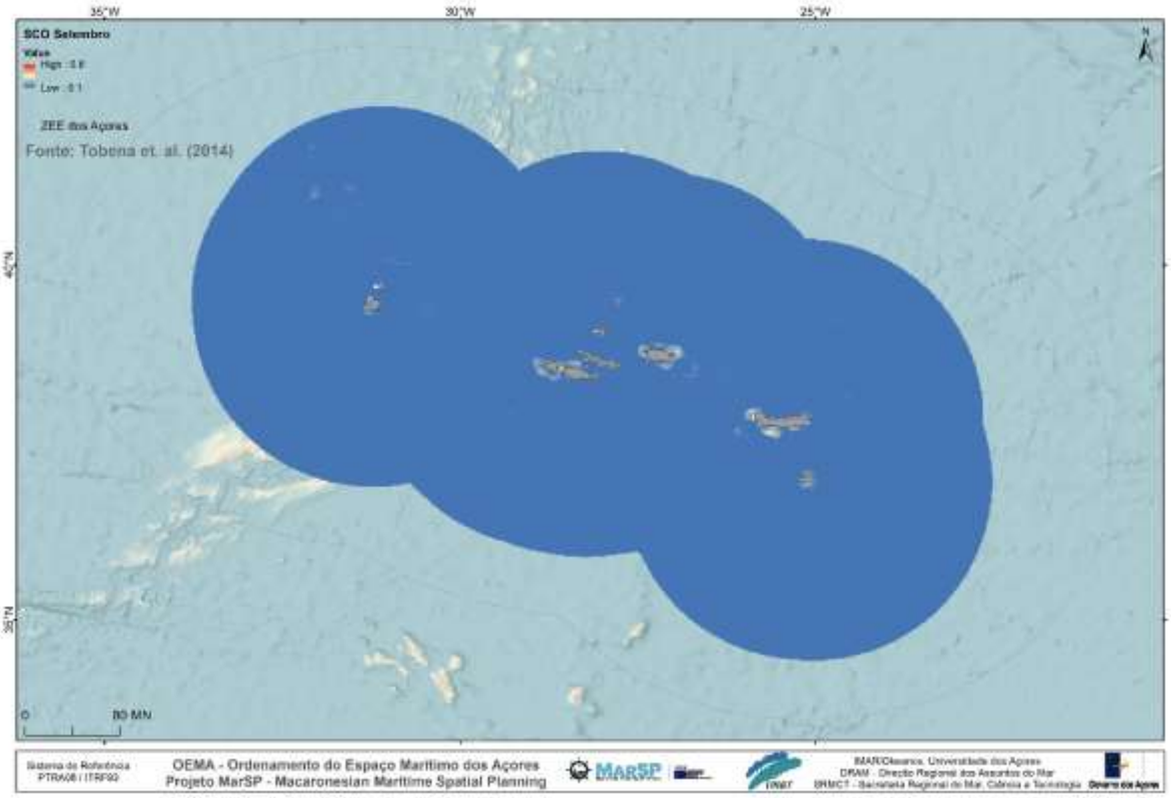
Spatial distribution of *Stenella coeruleoalba* (SCO), July



Spatial distribution of *Stenella coeruleoalba* (SCO), August

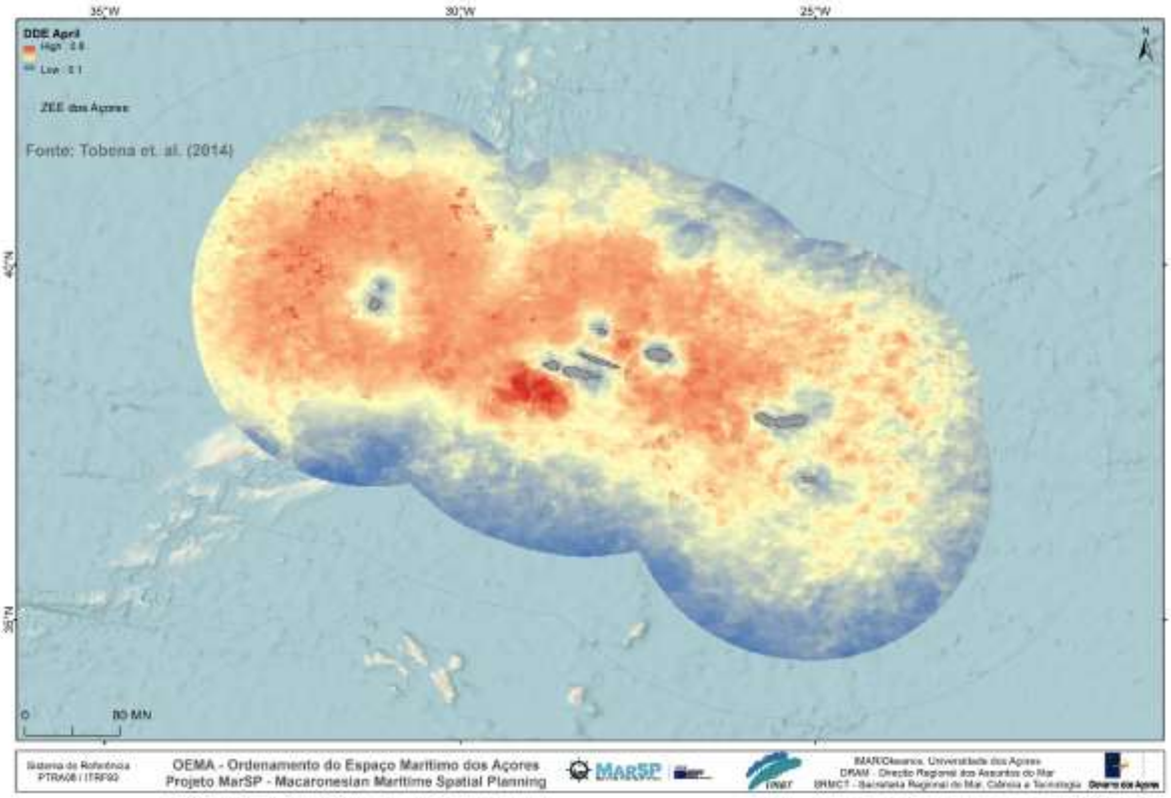


Spatial distribution of *Stenella coeruleoalba* (SCO), September

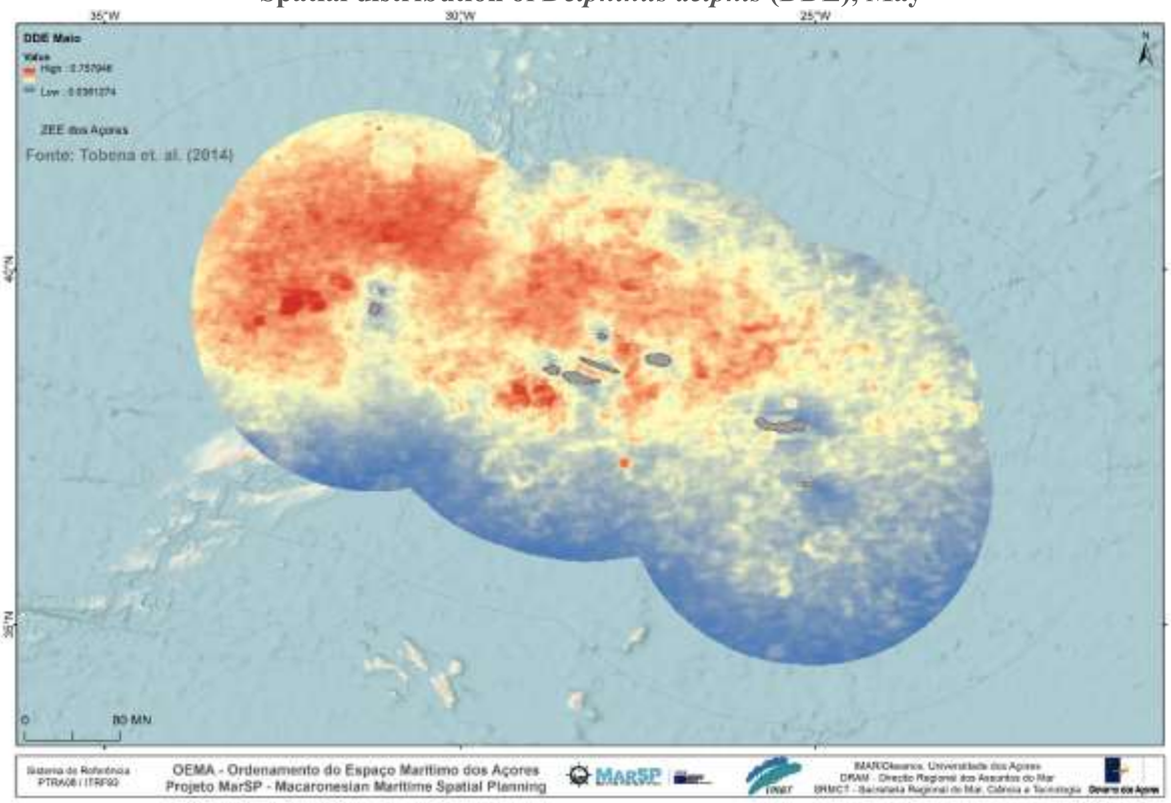


3.3.4. *Delphinus delphis* (from April to September) – 6 models

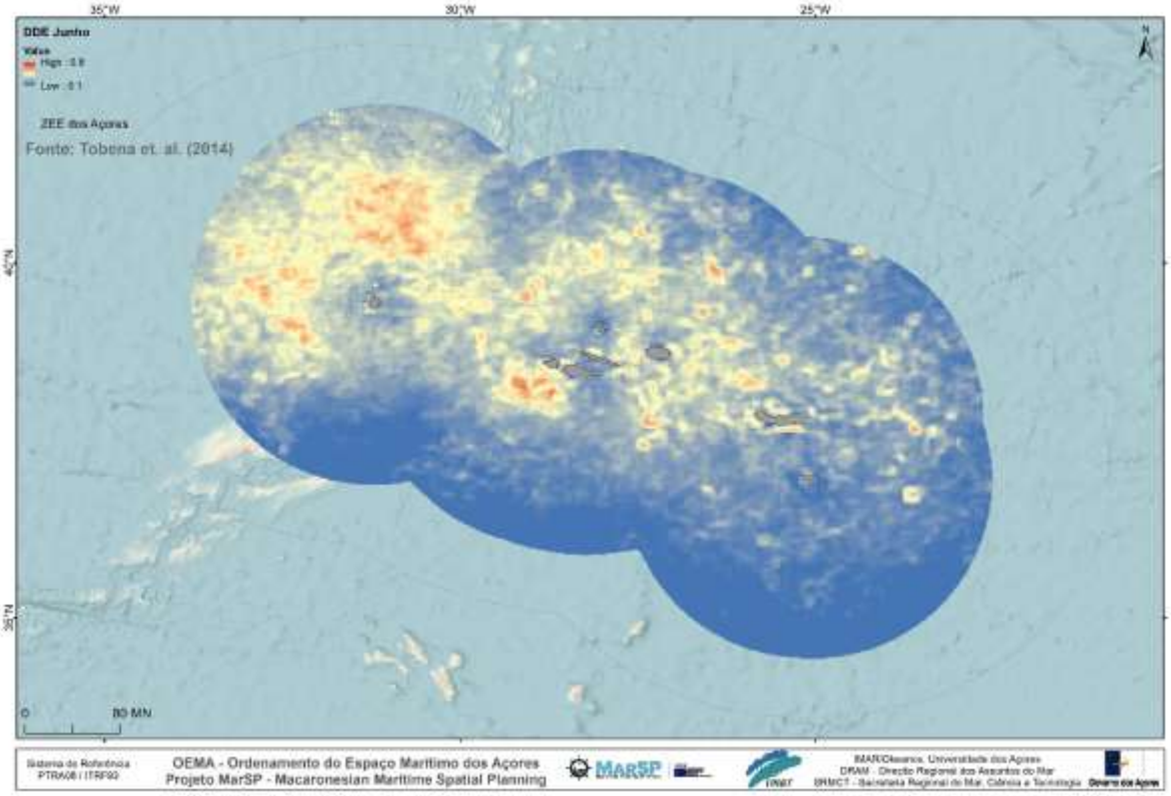
Spatial distribution of *Delphinus delphis* (DDE), April



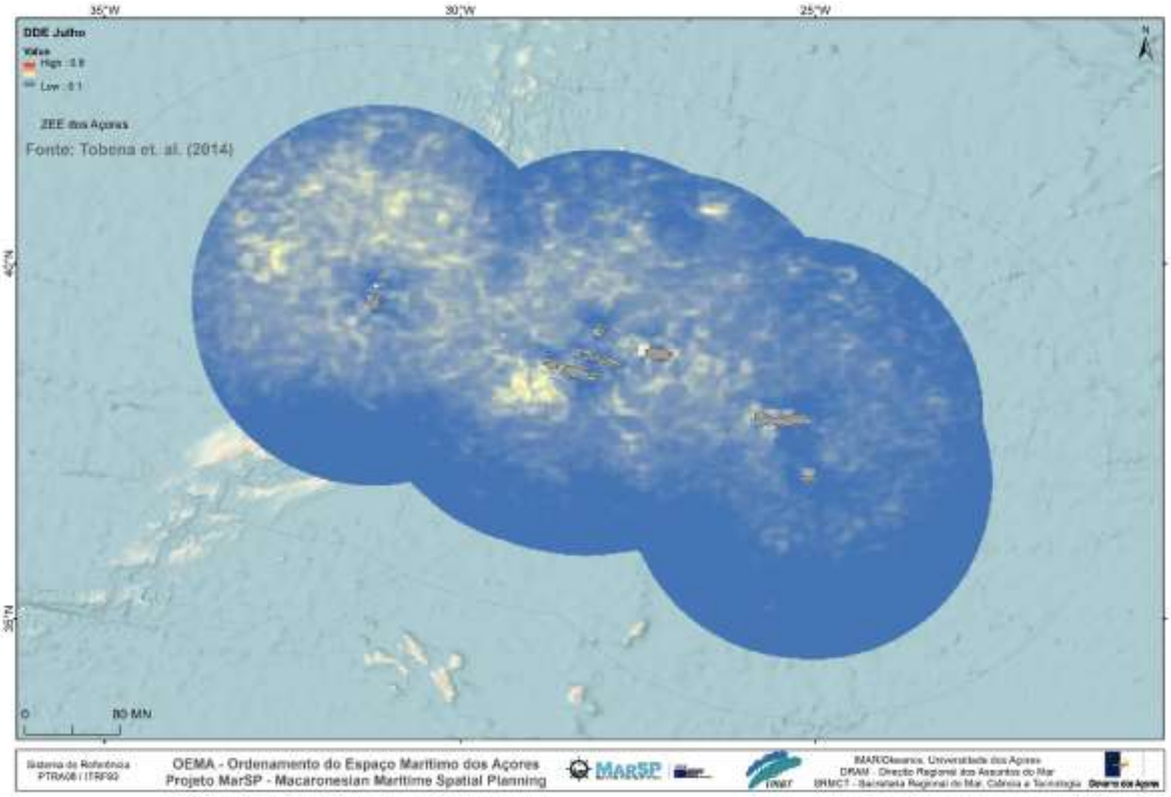
Spatial distribution of *Delphinus delphis* (DDE), May



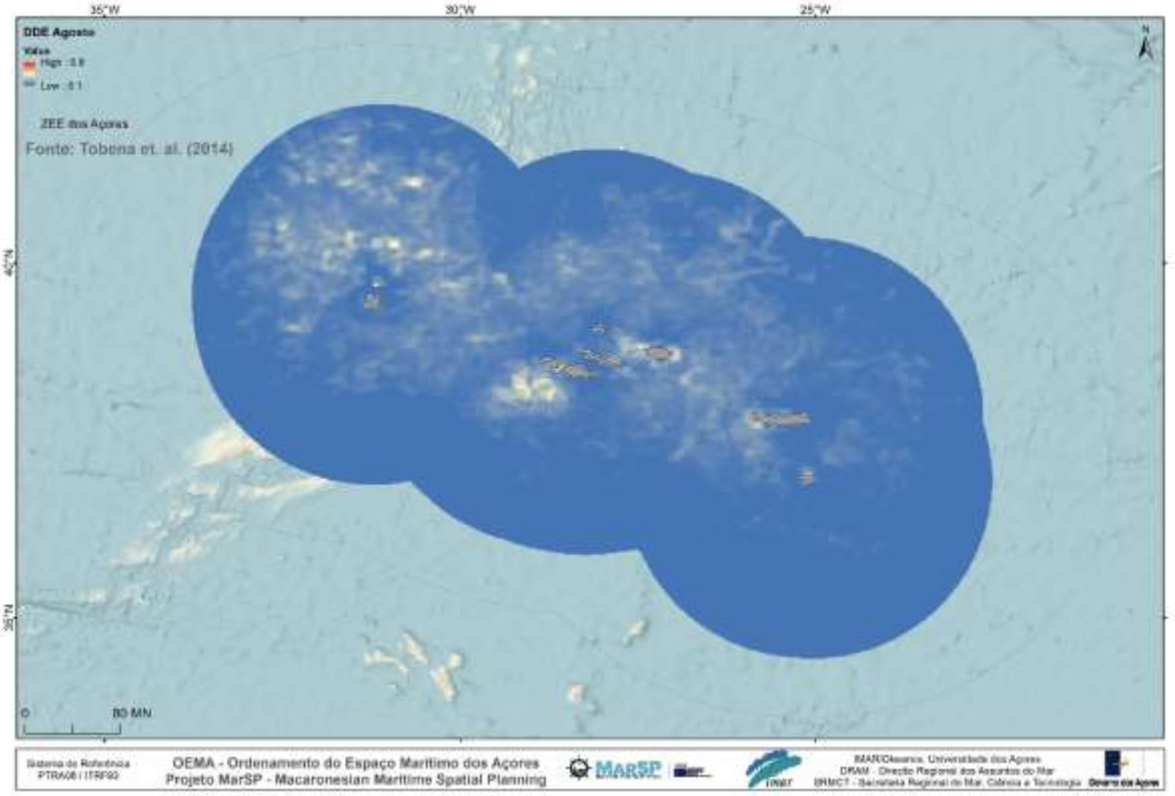
Spatial distribution of *Delphinus delphis* (DDE), June



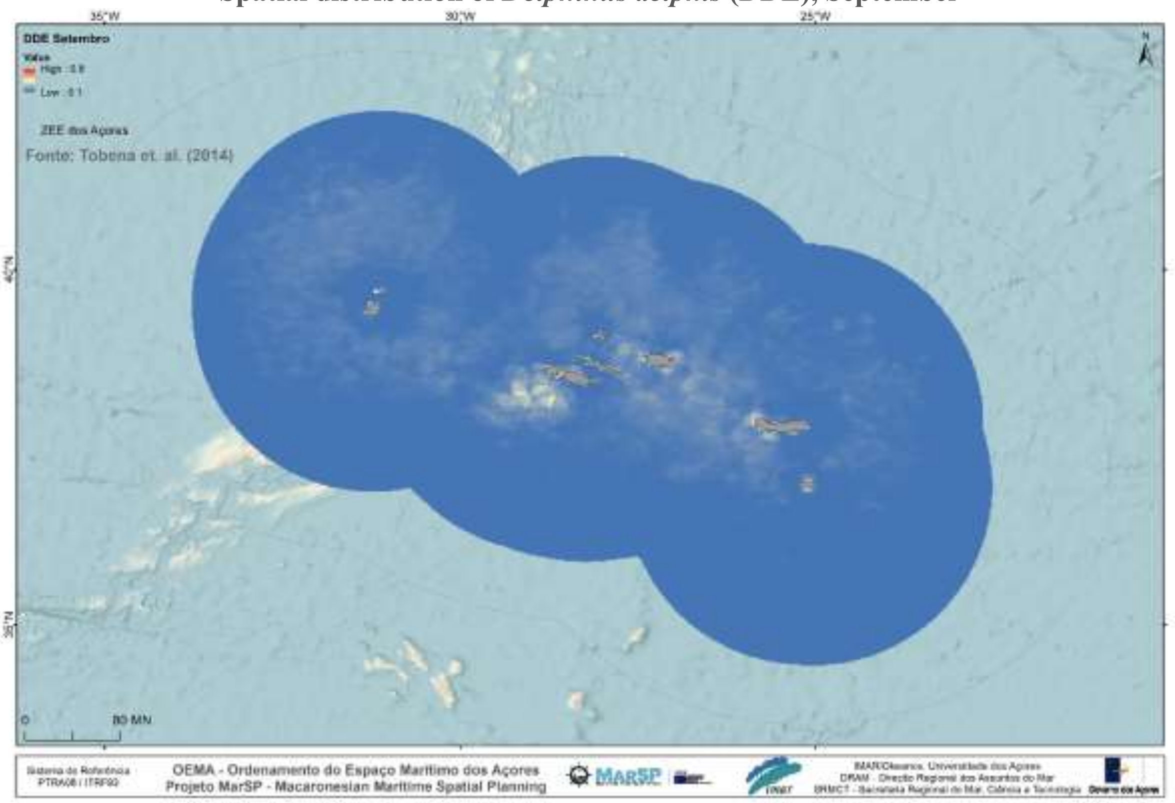
Spatial distribution of *Delphinus delphis* (DDE), July



Spatial distribution of *Delphinus delphis* (DDE), August



Spatial distribution of *Delphinus delphis* (DDE), September



3.4. Cetaceans / Big dolphins

Raster Dataset Series (24 models): 1704m (1,21Mb)

- *Orcinus orca* (from April to September) – 6 models
- *Grampus griseus* (from April to September) – 6 models
- *Pseudorca crassidens* (from April to September) – 6 models
- *Globicephala macrorhynchus* (from April to September) – 6 models

Year: 2014

Keywords: cetacean, spatio-temporal distribution, Azores, delphinids, species distribution models (SDMs), richness, MaxEnt

Summary: Mapped large delphinids habitat suitability and richness in the Azores.

Description: Marine spatial planning and ecological research call for high-resolution species distribution data. However, those data are still not available for most marine large vertebrates. The dynamic nature of oceanographic processes and the wide-ranging behaviour of many marine vertebrates create further difficulties, as distribution data must incorporate both the spatial and temporal dimensions. Cetaceans play an essential role in structuring and maintaining marine ecosystems and face increasing threats from human activities. The Azores holds a high diversity of cetaceans but the information about spatial and temporal patterns of distribution for this marine megafauna group in the region is still very limited. To tackle this issue, we created monthly predictive cetacean distribution maps for spring and summer months, using data collected by the Azores Fisheries Observer Programme between 2004 and 2009. We then combined the individual predictive maps to obtain species richness maps for the same period. Our results reflect a great heterogeneity in distribution among species and within species among different months. This heterogeneity reflects a contrasting influence of oceanographic processes on the distribution of cetacean species. However, some persistent areas of increased species richness could also be identified from our results. We argue that policies aimed at effectively protecting cetaceans and their habitats must include the principle of dynamic ocean management coupled with other area-based management such as marine spatial planning. This work was supported by FEDER funds, through the Competitiveness Factors Operational Programme - COMPETE, by national funds, through FCT - Foundation for Science and Technology, under project TRACE (PTDC/ MAR/74071/2006), and by regional funds, through DRCT/SRCTE, under projects MAPCET (M2.1.2/F/012/2011) and 2020 (M2.1.2/I/026/2011). We acknowledge funds provided by FCT to MARE, through the strategic project UID/MAR/04292/2013. RP is supported by an FCT postdoctoral grant (SFRH/BPD/108007/2015); MAS is supported by Program Investigator FCT (IF/00943/2013) and MT was supported by a research fellowship under the Exploratory project (IF/00943/2013/CP1199/CT0001) that also paid the fees for this open-access publication. IF/00943/2013 and IF/00943/2013/CP1199/CT0001 are funded by FSE and MCTES, through POPH and QREN.

Credits: IMAR, Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-33.775034	East	-22.508365
North	42.225002	South	34.425000

Citation Contacts:
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS rcabprieto@gmail.com

Point of Contact: :
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
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Y ORIGIN -400
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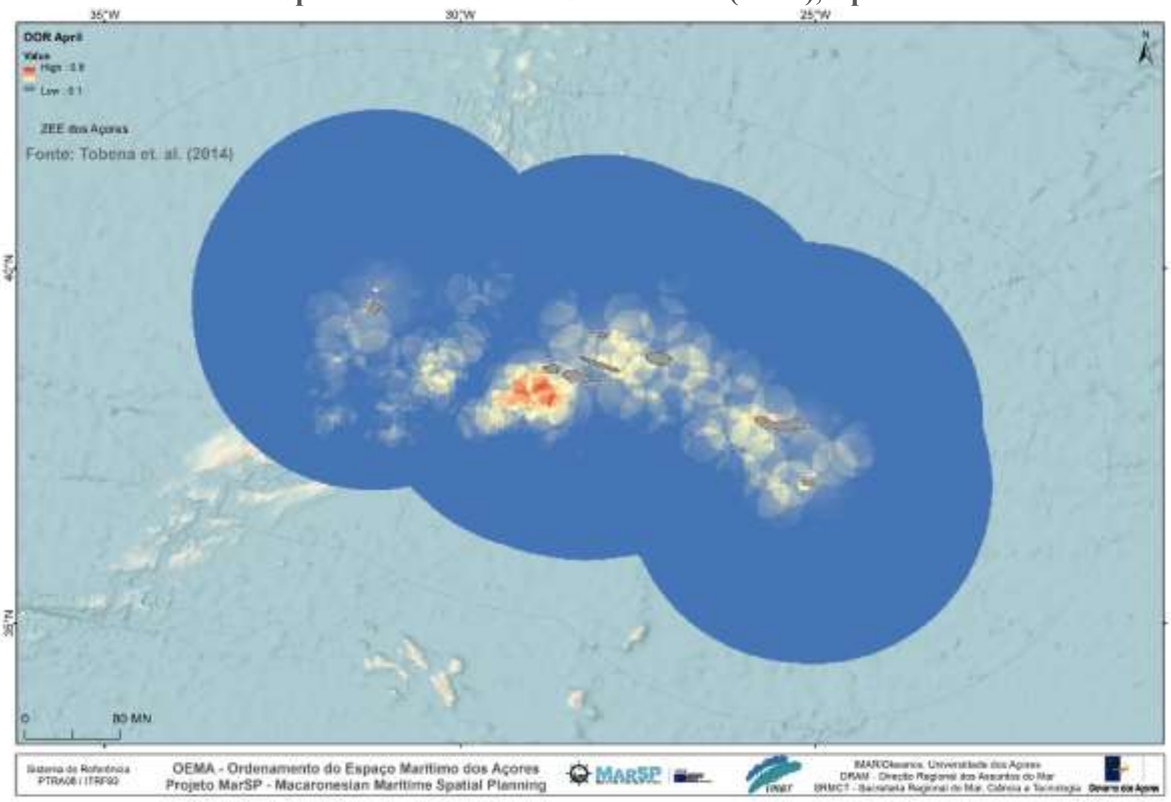
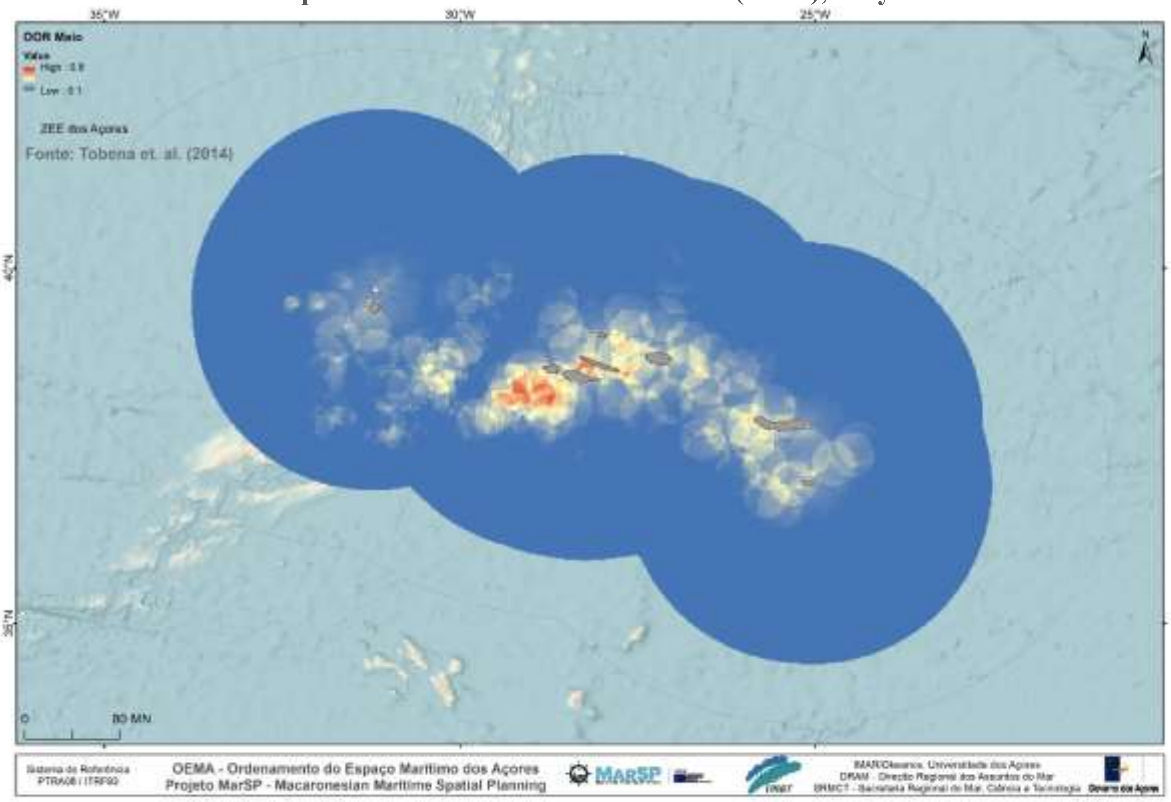
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3.4.1. *Orcinus orca* (from April to September) – 6 models

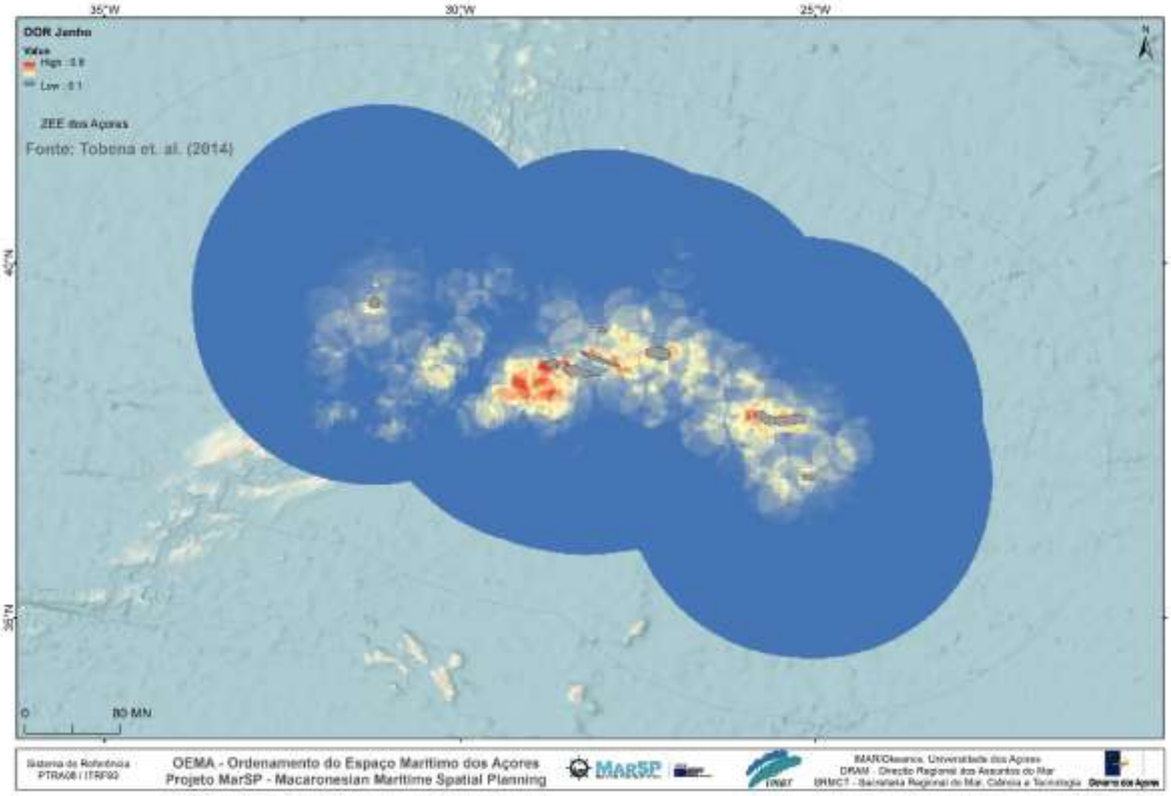
Spatial distribution of *Orcinus orca* (OOR), April



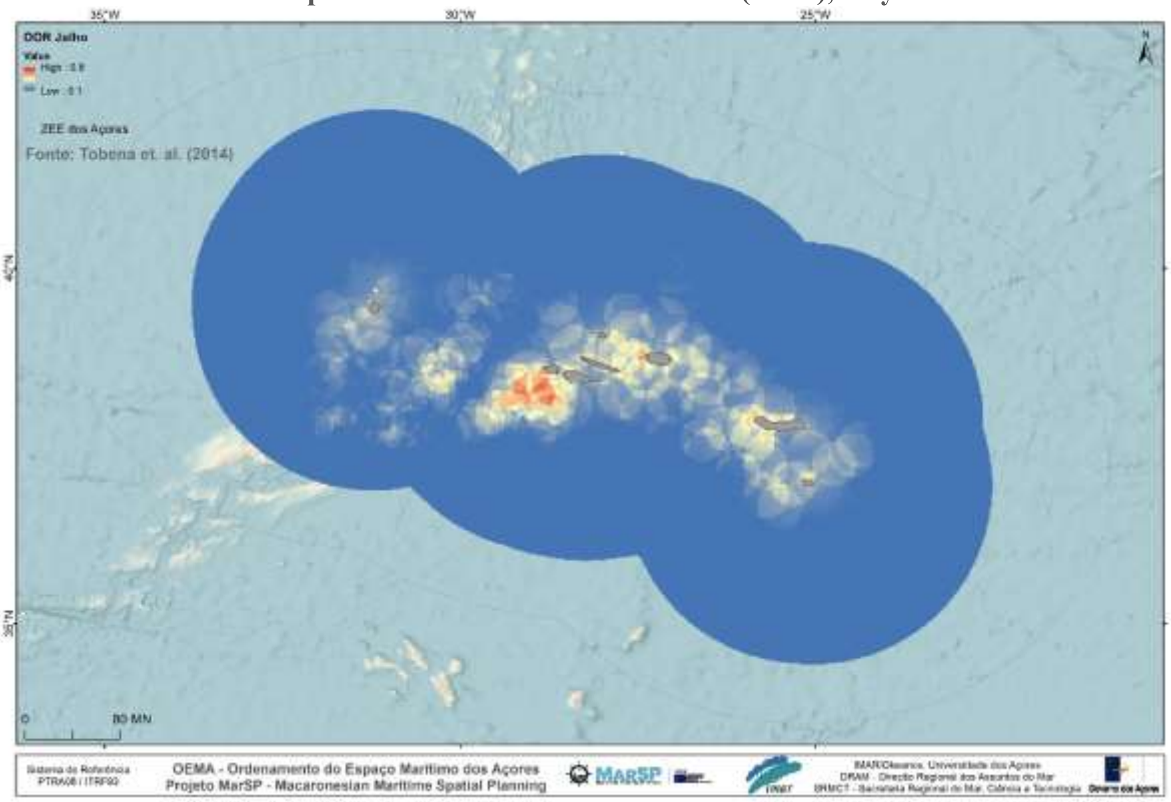
Spatial distribution of *Orcinus orca* (OOR), May



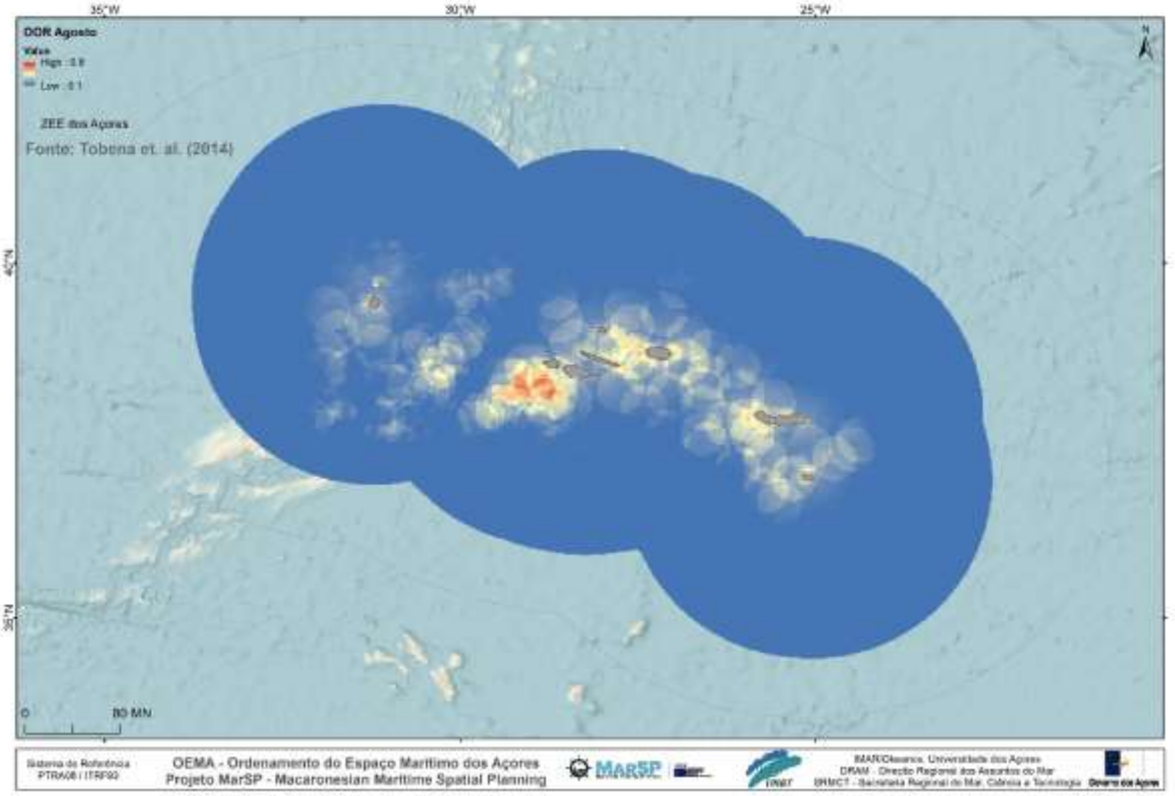
Spatial distribution of *Orcinus orca* (OOR), June



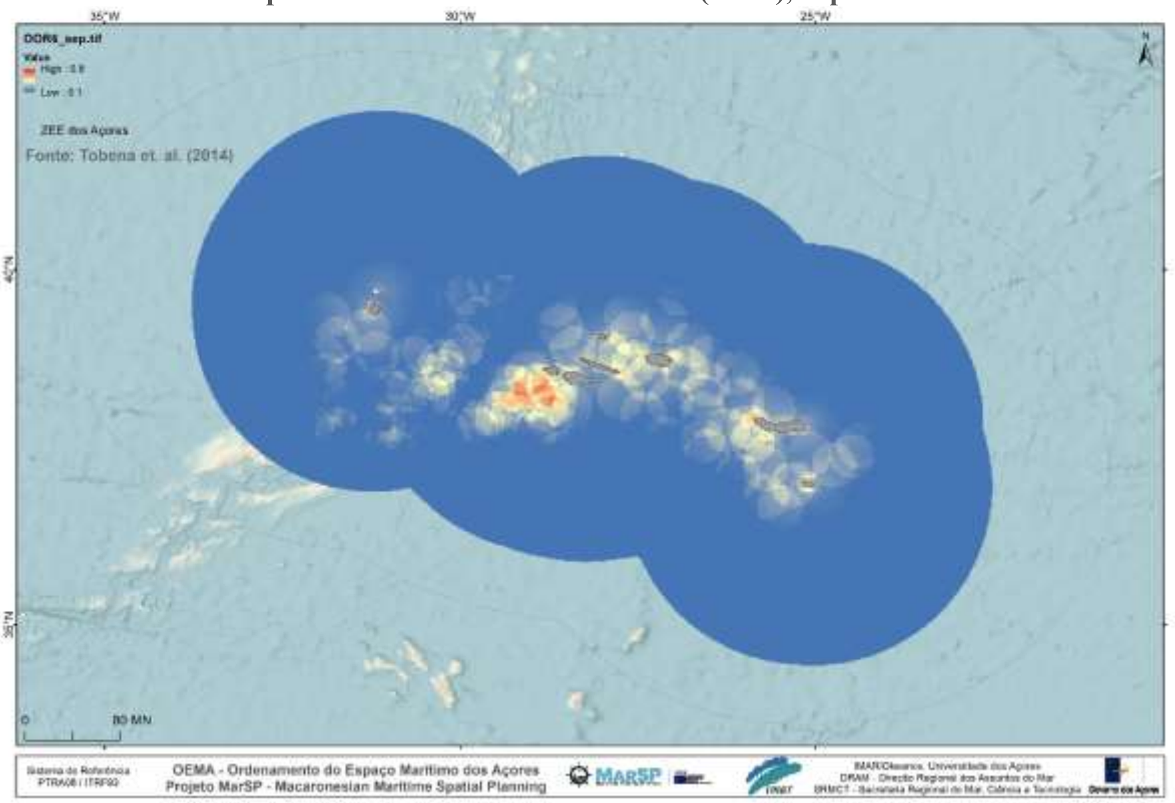
Spatial distribution of *Orcinus orca* (OOR), July



Spatial distribution of *Orcinus orca* (OOR), August

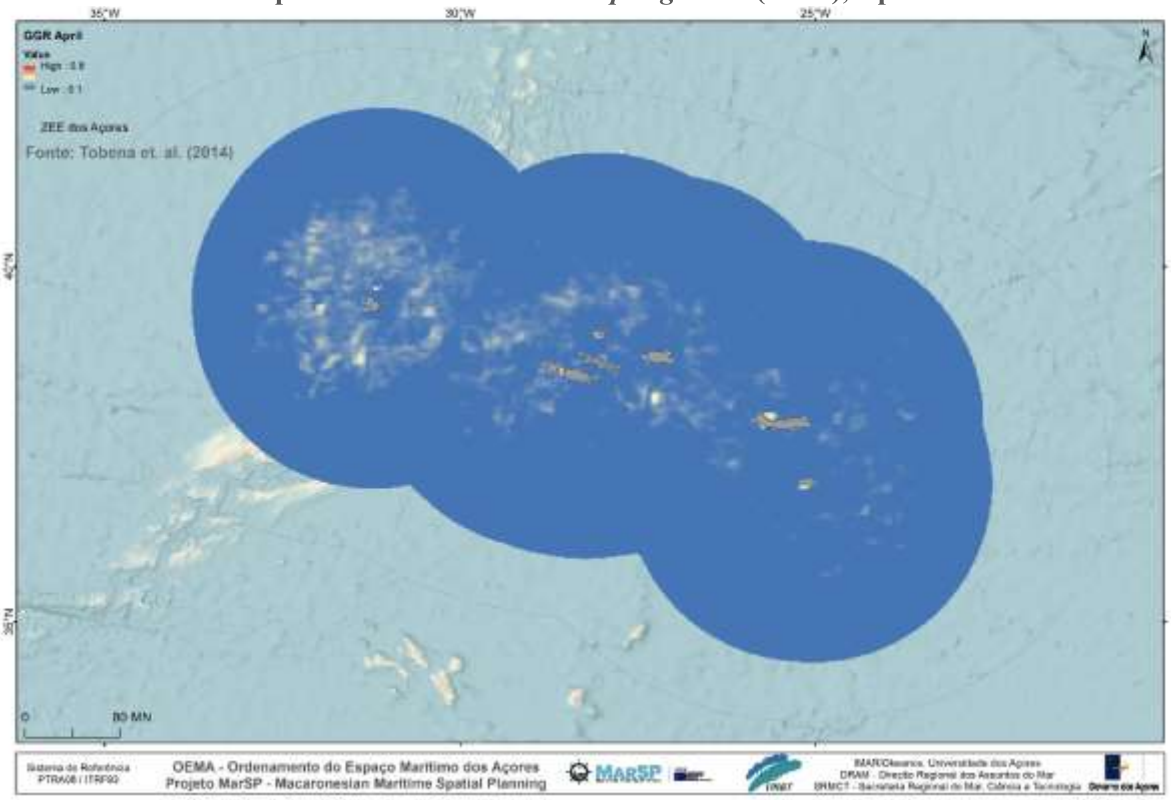


Spatial distribution of *Orcinus orca* (OOR), September

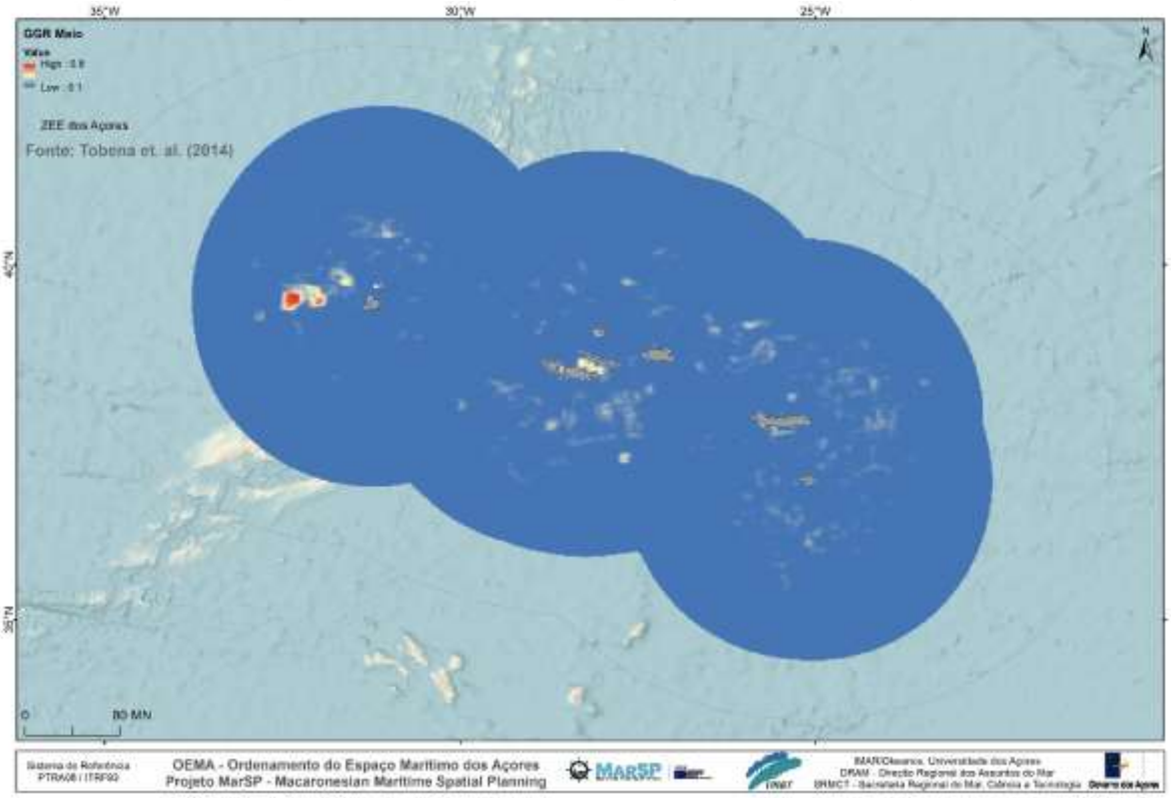


3.4.2. *Grampus griseus* (from April to September) – 6 models

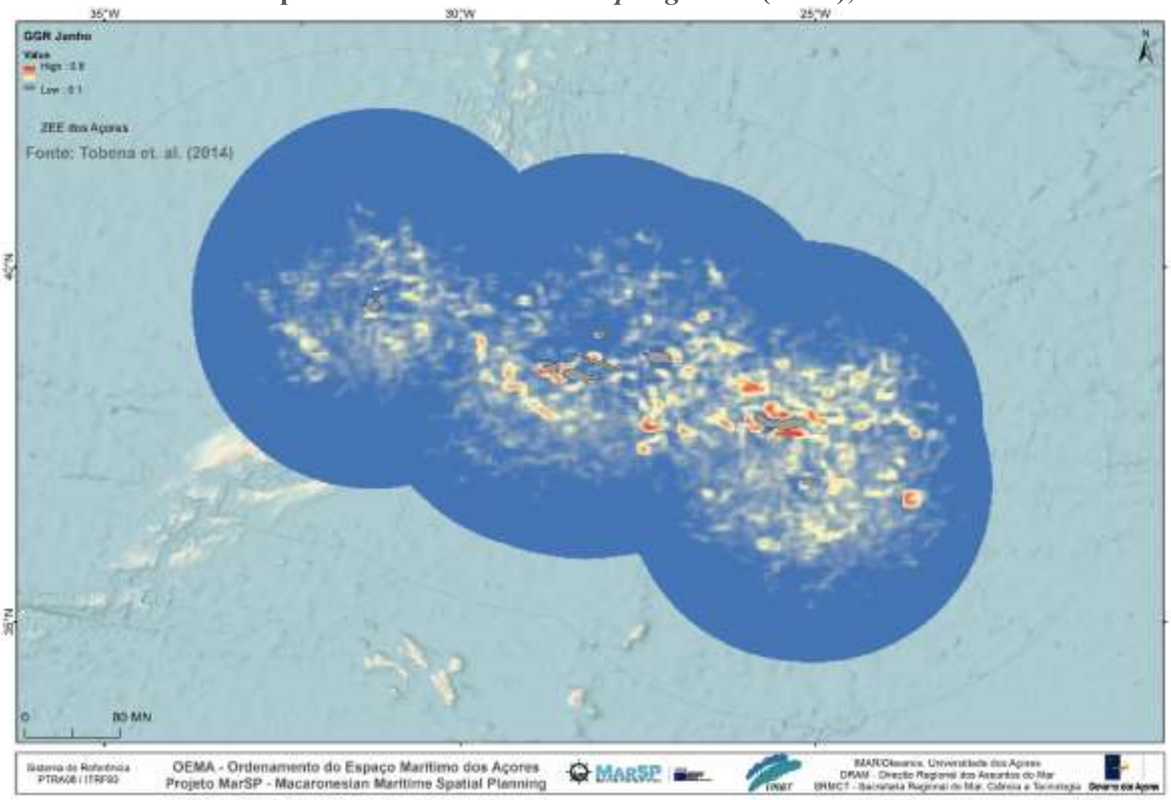
Spatial distribution of *Grampus griseus* (GGR), April



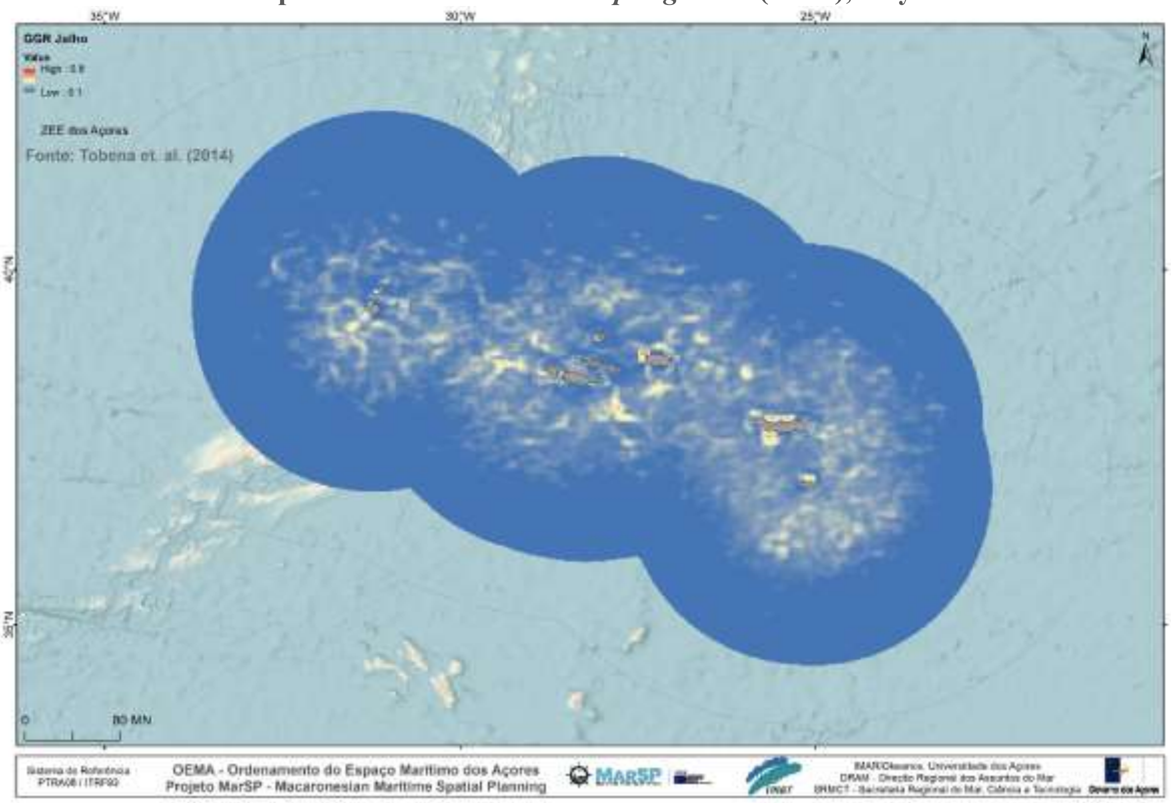
Spatial distribution of *Grampus griseus* (GGR), May



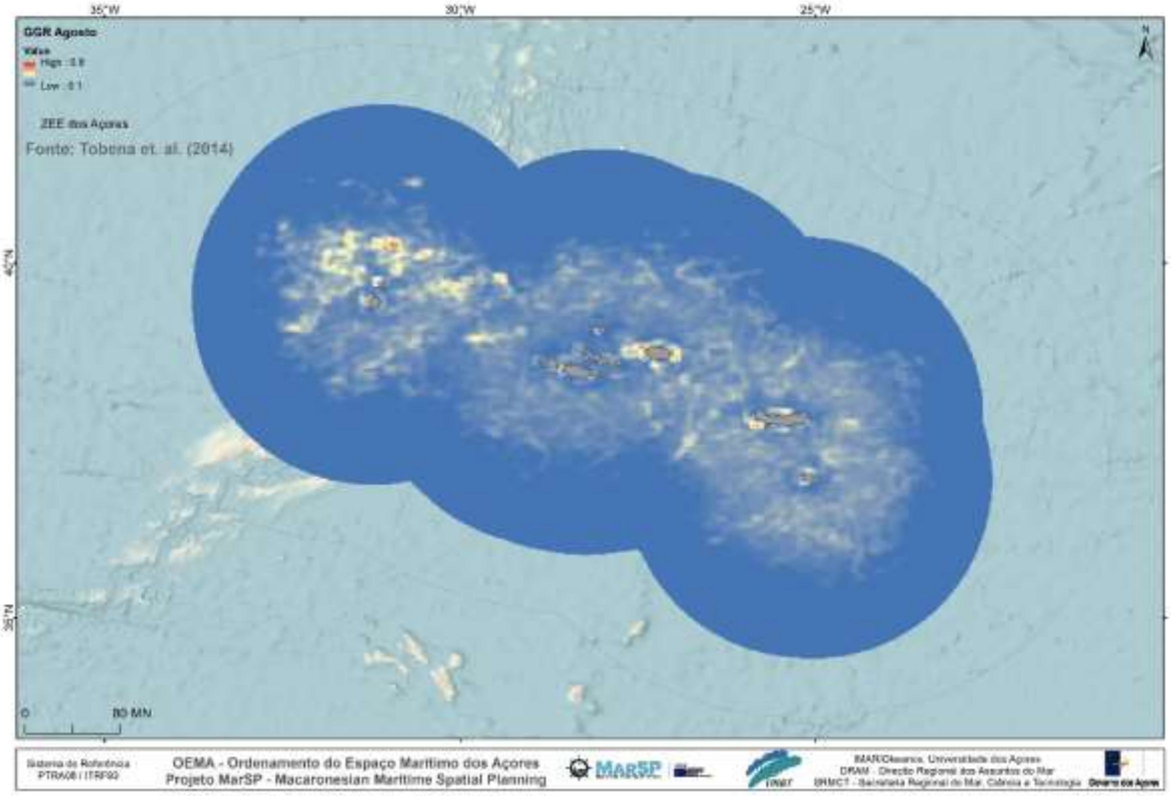
Spatial distribution of *Grampus griseus* (GGR), June



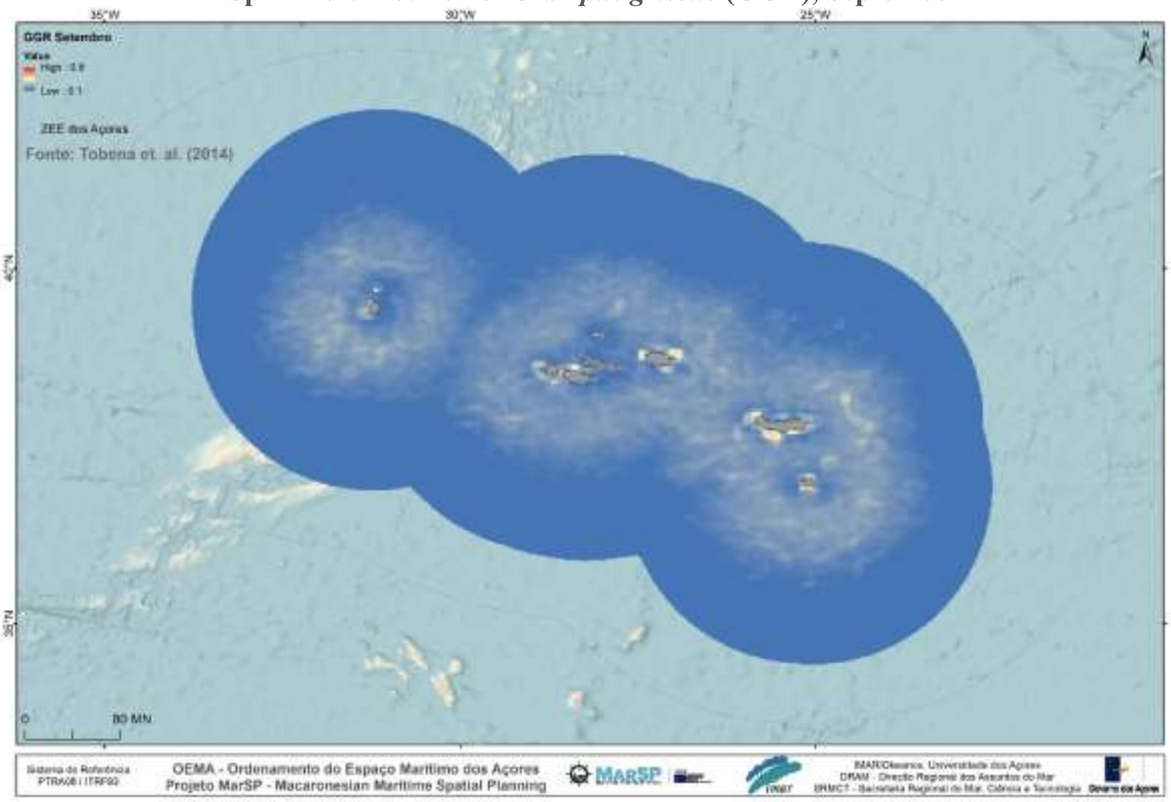
Spatial distribution of *Grampus griseus* (GGR), July



Spatial distribution of *Grampus griseus* (GGR), August

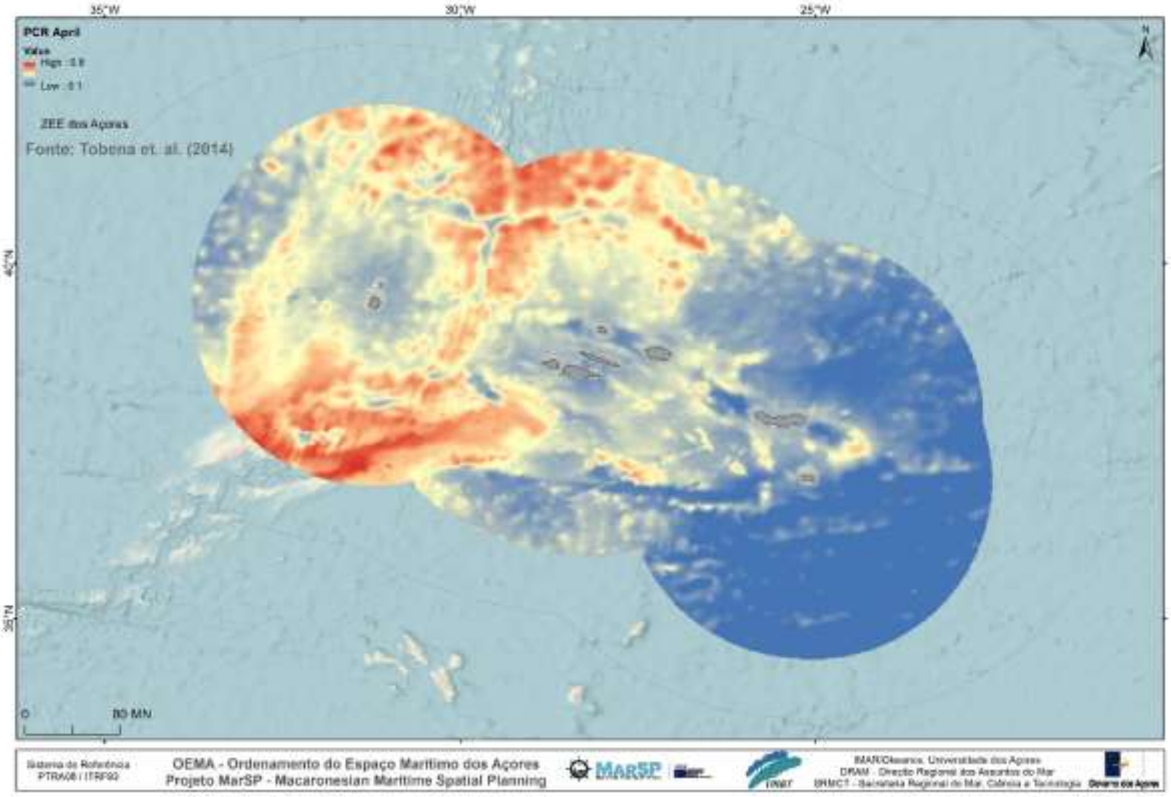


Spatial distribution of *Grampus griseus* (GGR), September

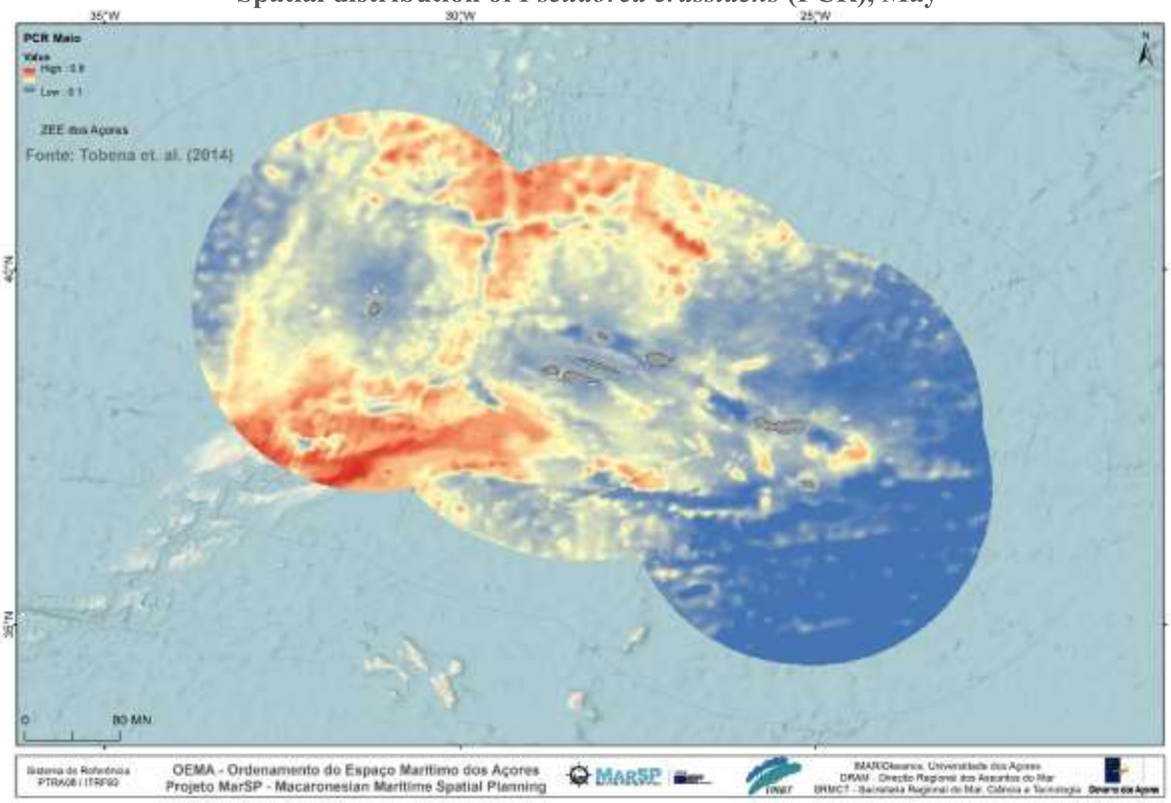


3.4.3. *Pseudorca crassidens* (from April to September) – 6 models

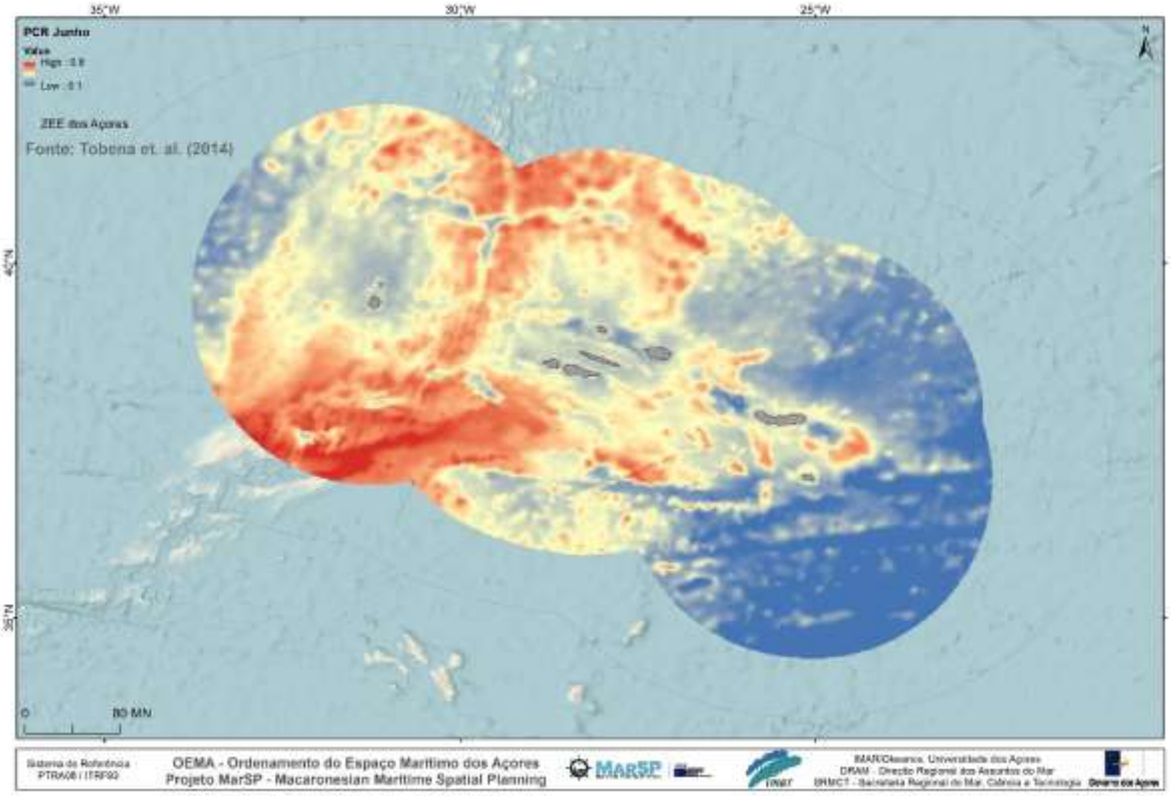
Spatial distribution of *Pseudorca crassidens* (PCR), April



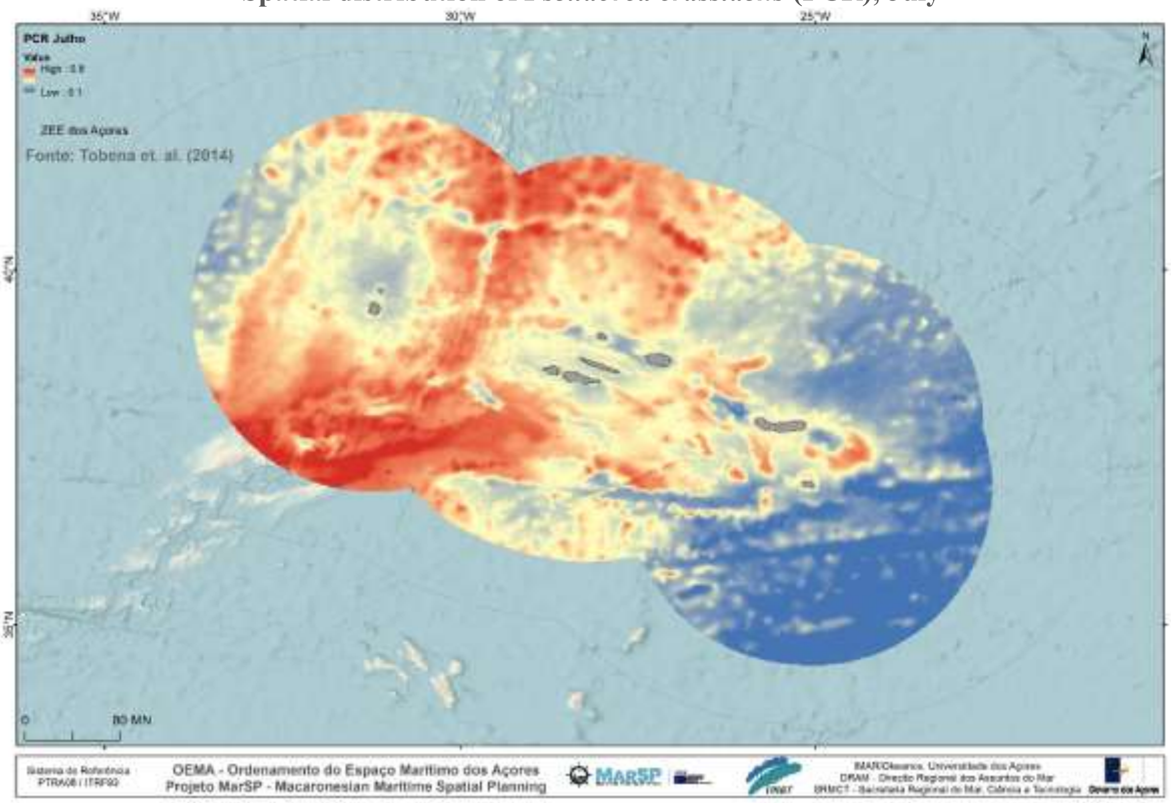
Spatial distribution of *Pseudorca crassidens* (PCR), May



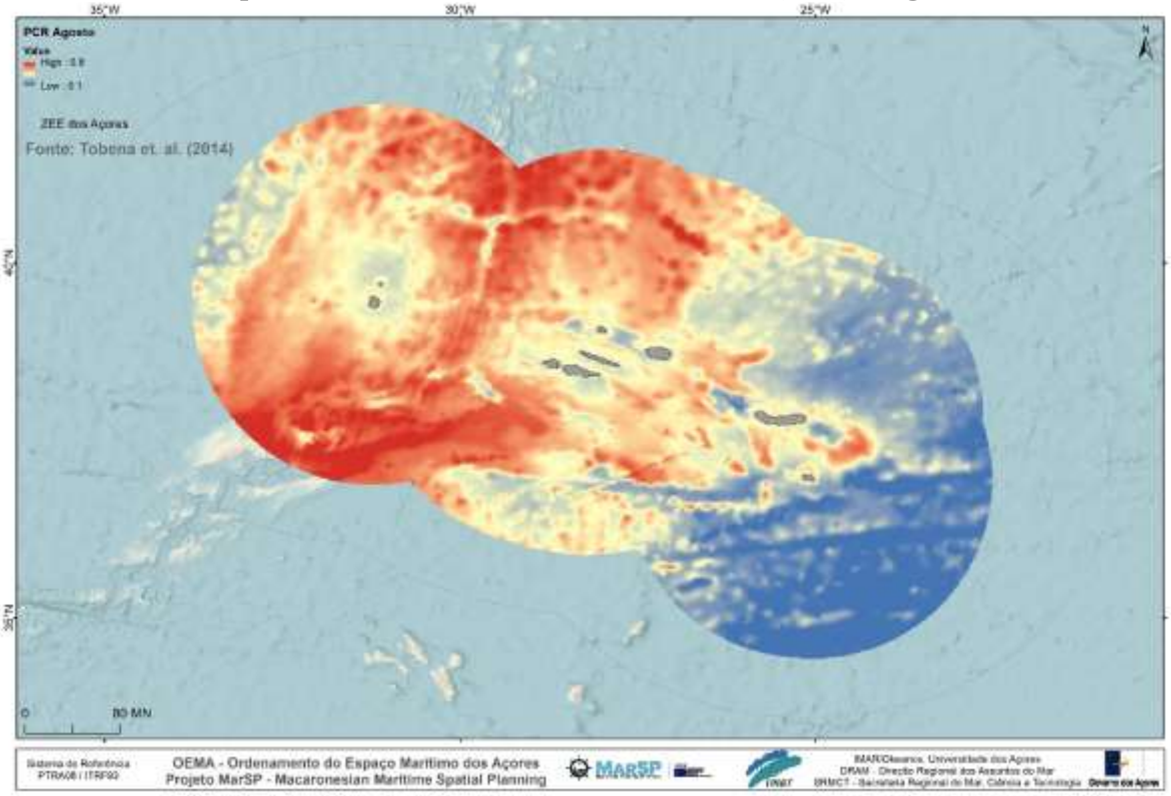
Spatial distribution of *Pseudorca crassidens* (PCR), June



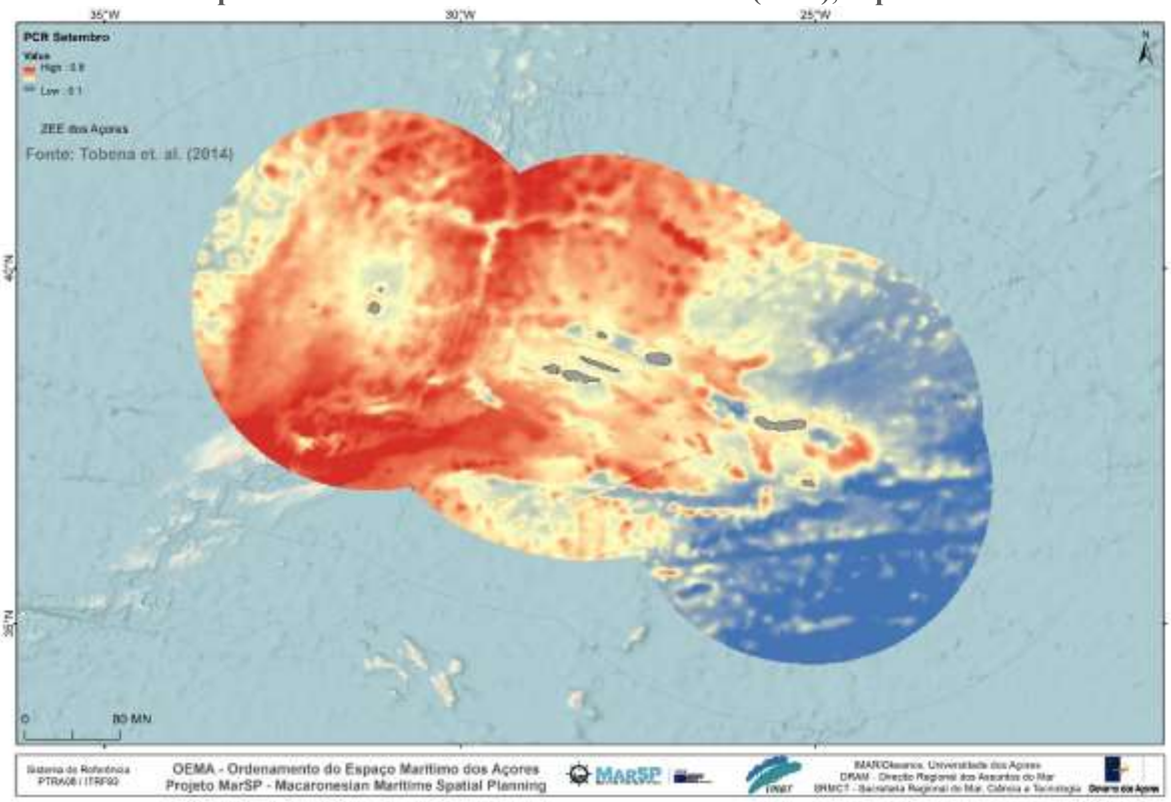
Spatial distribution of *Pseudorca crassidens* (PCR), July



Spatial distribution of *Pseudorca crassidens* (PCR), August

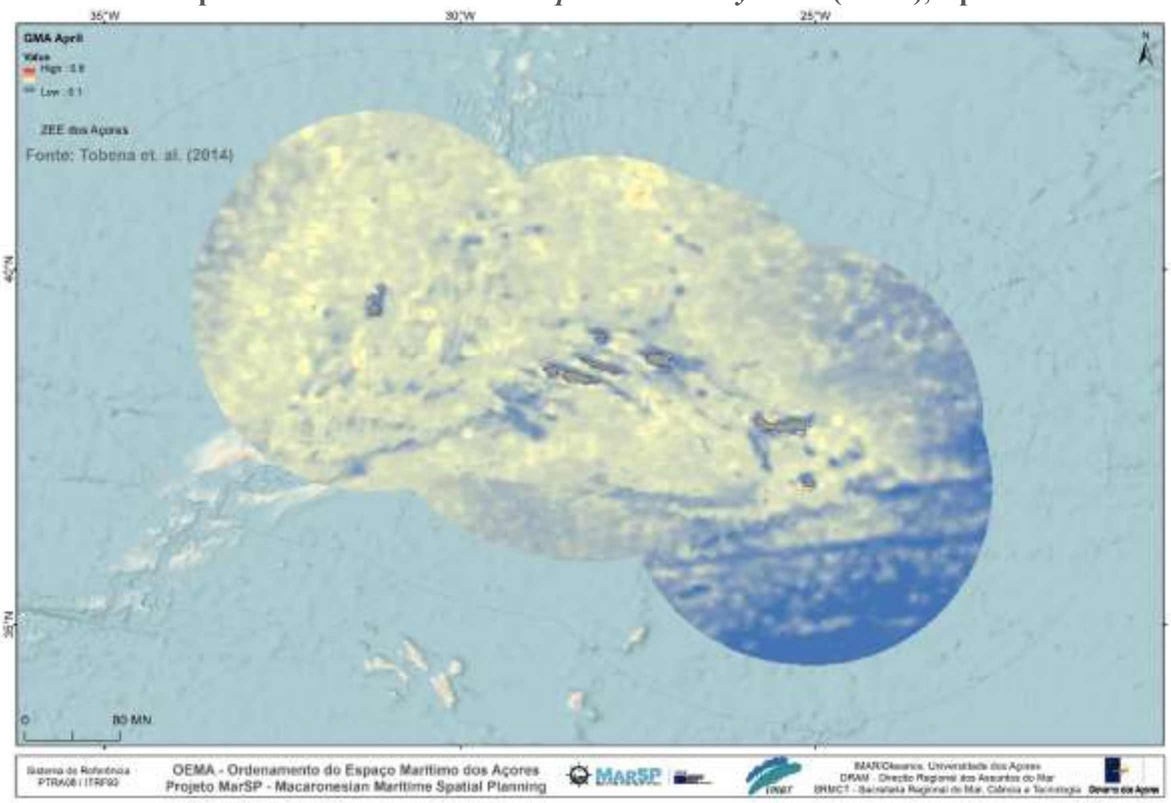


Spatial distribution of *Pseudorca crassidens* (PCR), September

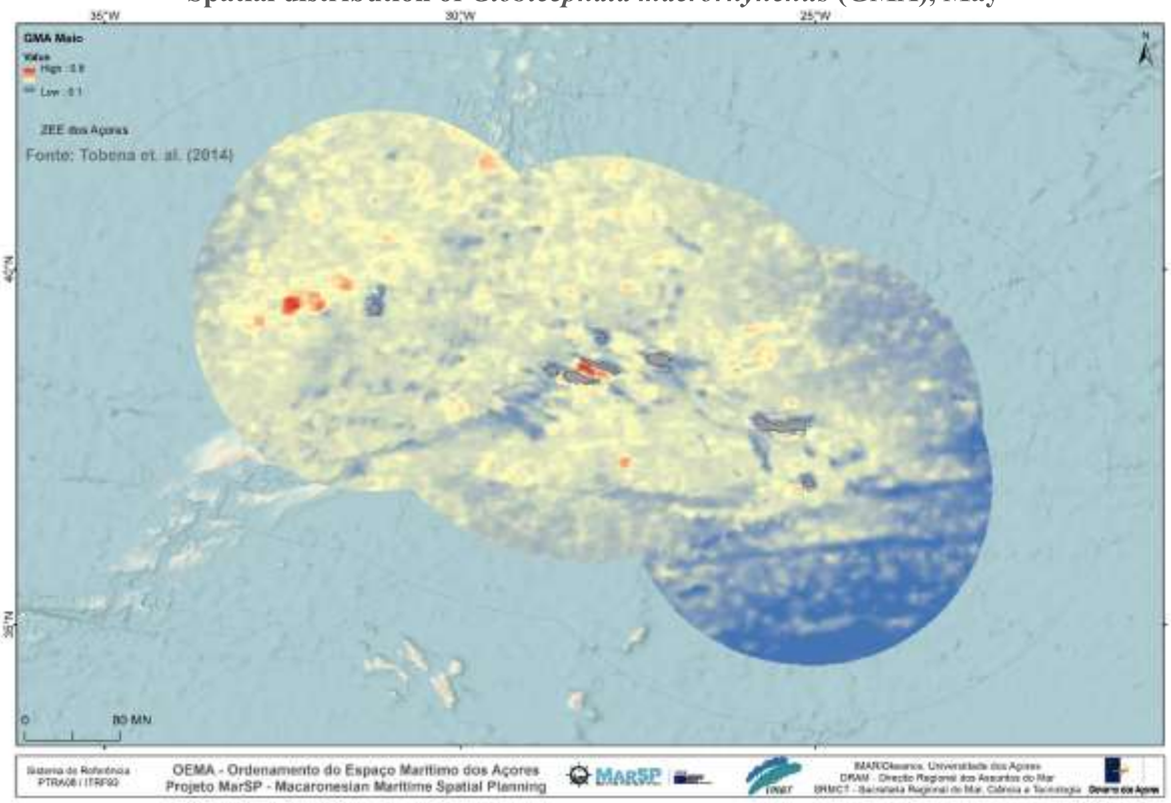


3.4.4. *Globicephala macrorhynchus* (from April to September) – 6 models

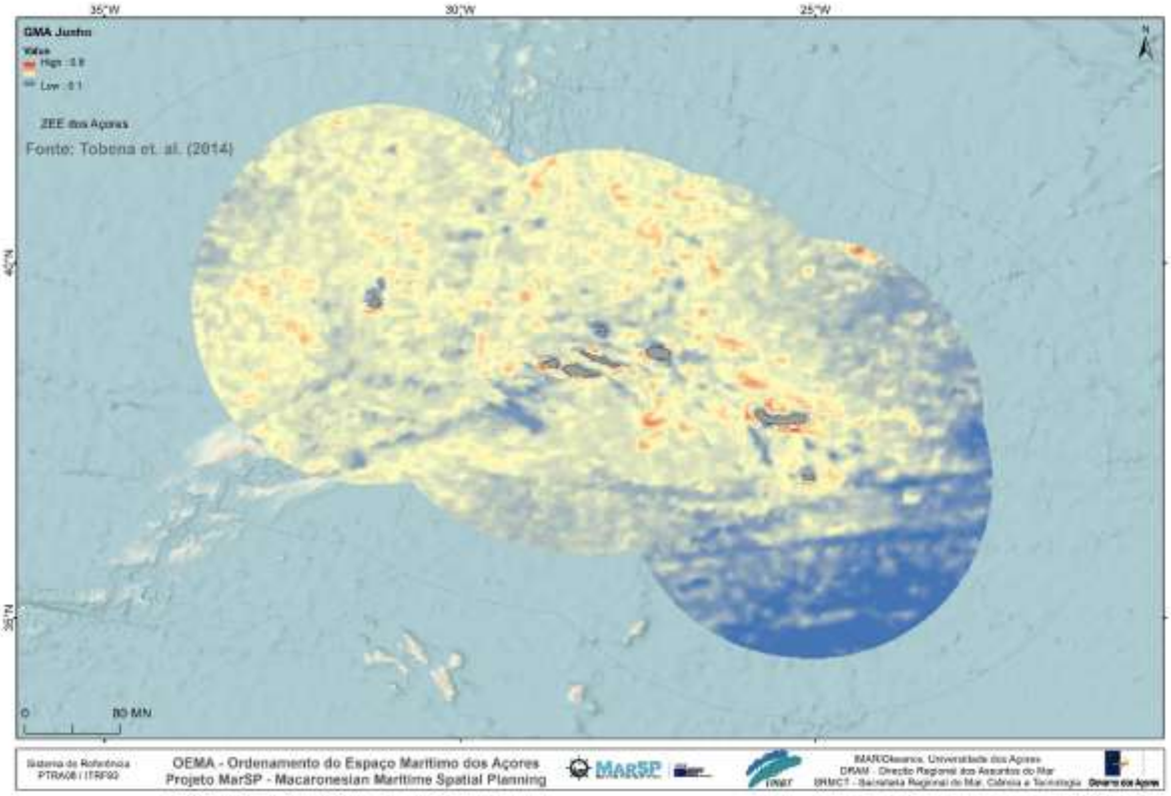
Spatial distribution of *Globicephala macrorhynchus* (GMA), April



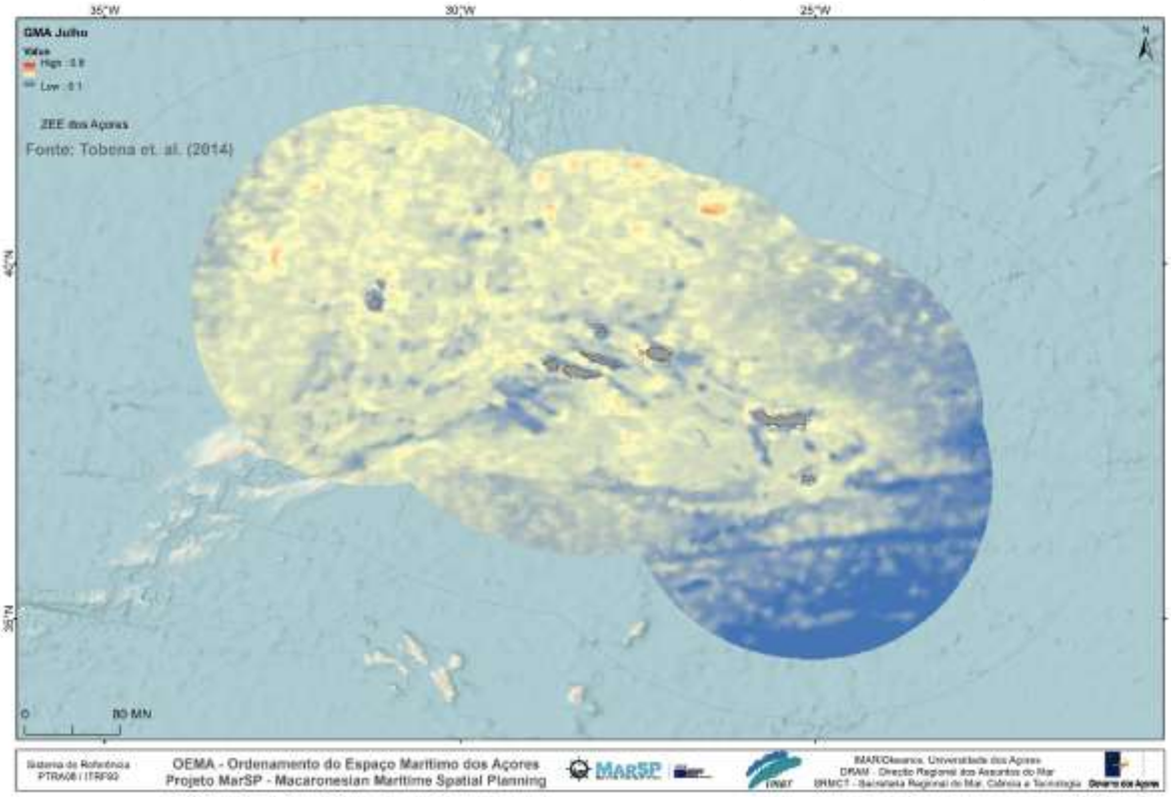
Spatial distribution of *Globicephala macrorhynchus* (GMA), May



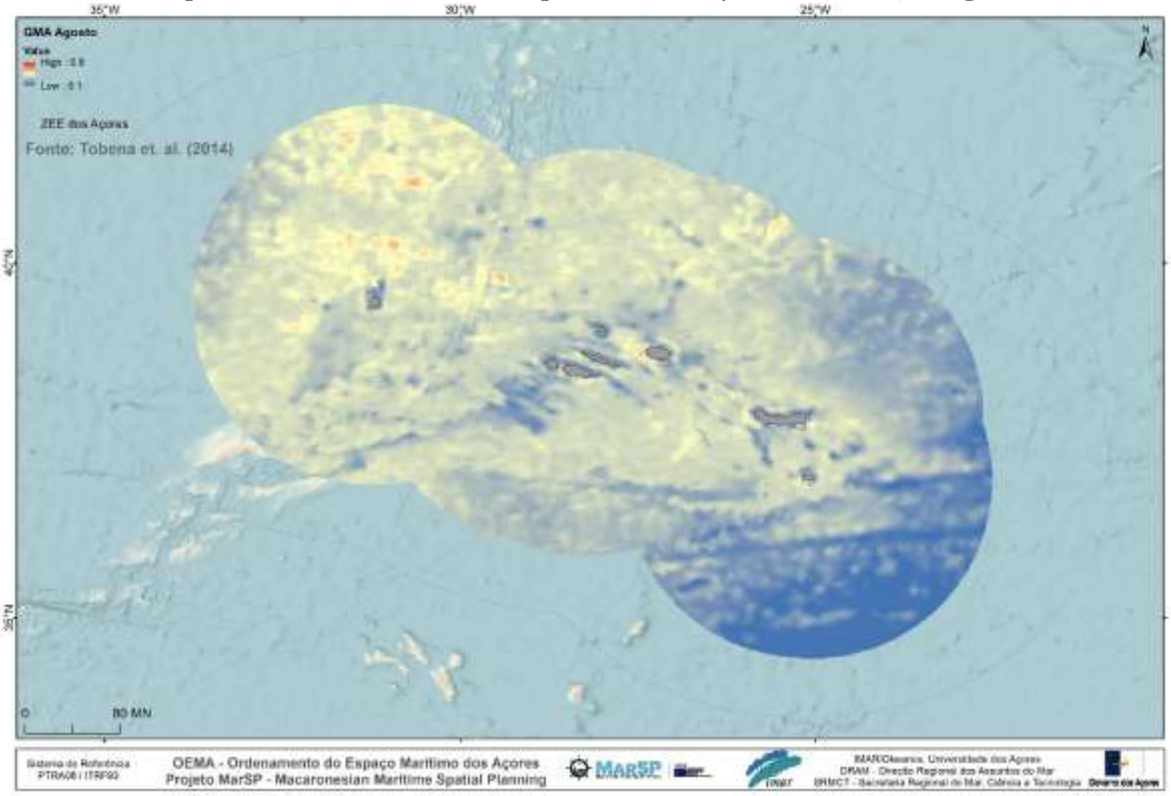
Spatial distribution of *Globicephala macrorhynchus* (GMA), June



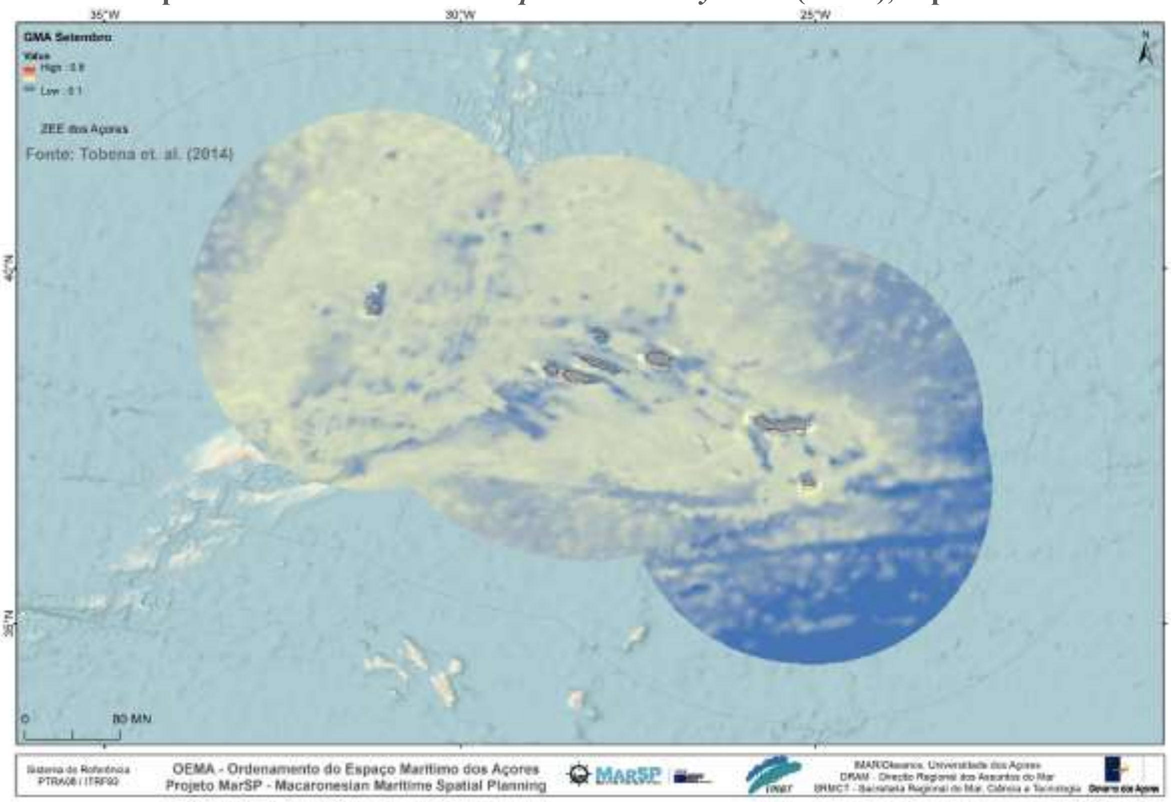
Spatial distribution of *Globicephala macrorhynchus* (GMA), July



Spatial distribution of *Globicephala macrorhynchus* (GMA), August



Spatial distribution of *Globicephala macrorhynchus* (GMA), September



3.5. Cold-water Corals

Raster Dataset Series (15 models): 1130m (4.17 MB)

Habitat Suitability Modelling is an innovative GIS-based method used to produce predictive maps of where elements (species, ecological community type) are likely to occur and likely to not occur. The probability of occurrence is quantified and is directly related to underlying environmental variables and the locations of known occurrences. There have been used presence models to make the predictive distribution.

This Predictive Distribution Modelling of Cold-Water Corals in the Azorean sea has been developed inside the Atlas project, and it has been made by the researcher Gerald H. Taranto. On these group of layers, were only modelled 15 cold water-coral that had more than 15 quantified occurrences after filtering the database of cold-water corals. The genus of corals was modelled until 2000 meters of depth, because in deeper areas sampling effort was minimal.

In this dataset, there are information about the Predictive Distribution Modelling of 15 cold water-corals:

- *Acanella arbuscula;*
- *Acanthogorgia* spp.*;*
- *Callogorgia verticillata;*
- Coralliidae;
- *Dentomuricea* aff. *meteor;*
- *Errina dabneyi;*
- *Leiopathes* sp.*;*
- *Lophelia pertusa;*
- *Madrepora oculata;*
- *Narella bellissima;*
- *Narella versluysi;*
- *Paracalyptrophora josephinae;*
- *Paragorgia johnsoni;*
- *Solenosmilia variabilis;*
- *Viminella flagellum.*

3.5.1. Acanella arbuscula

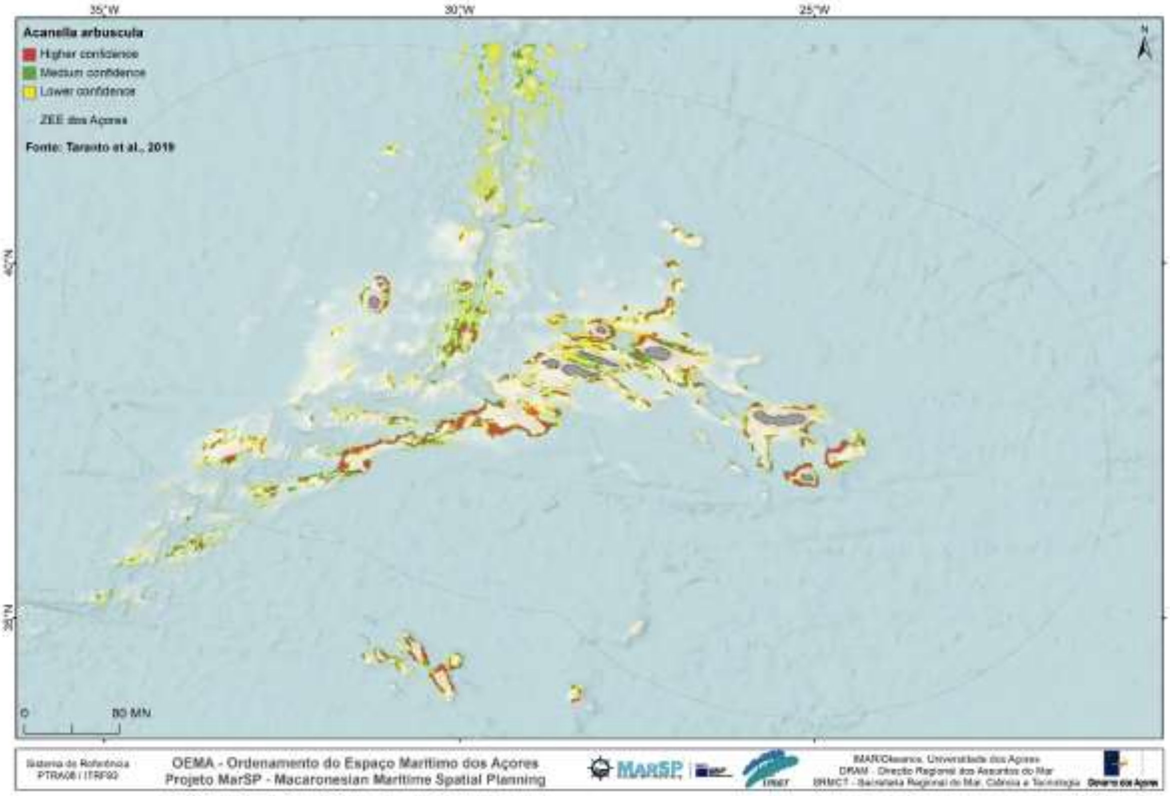
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Acanella arbuscula*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Acanella arbuscula*.

Cold-water corals in the Azores: *Acanella arbuscula*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
INDIVIDUAL'S NAME Gerald H. Taranto
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS gh.taranto@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001

M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

3.5.2. *Acanthogorgia* spp.

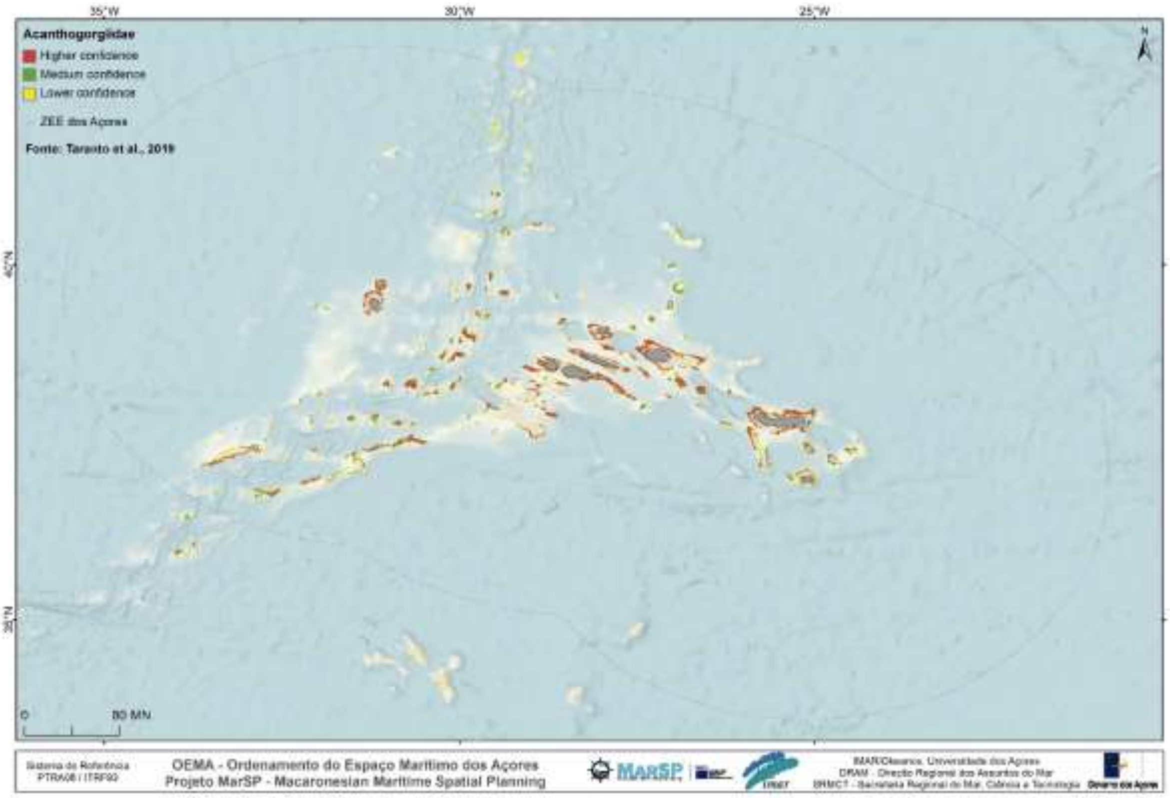
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral genus *Acanthogorgia*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral genus *Acanthogorgia*.

Cold-water corals in the Azores: *Acanthogorgia* spp.



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
INDIVIDUAL'S NAME Gerald H. Taranto
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS gh.taranto@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3.5.3. *Callogorgia verticillata*

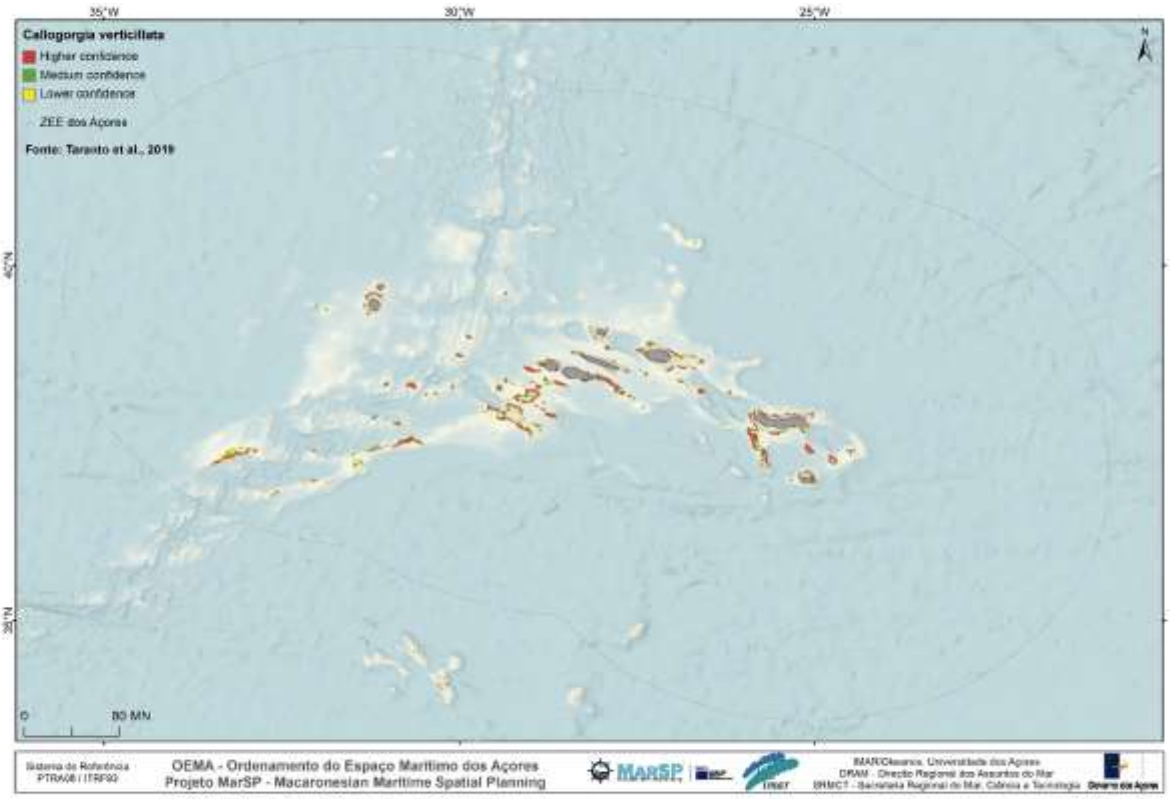
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Callogorgia verticillata*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Callogorgia verticillata*.

Cold-water corals in the Azores: *Callogorgia verticillata*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
INDIVIDUAL'S NAME Gerald H. Taranto
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

3.5.4. Coralliidae

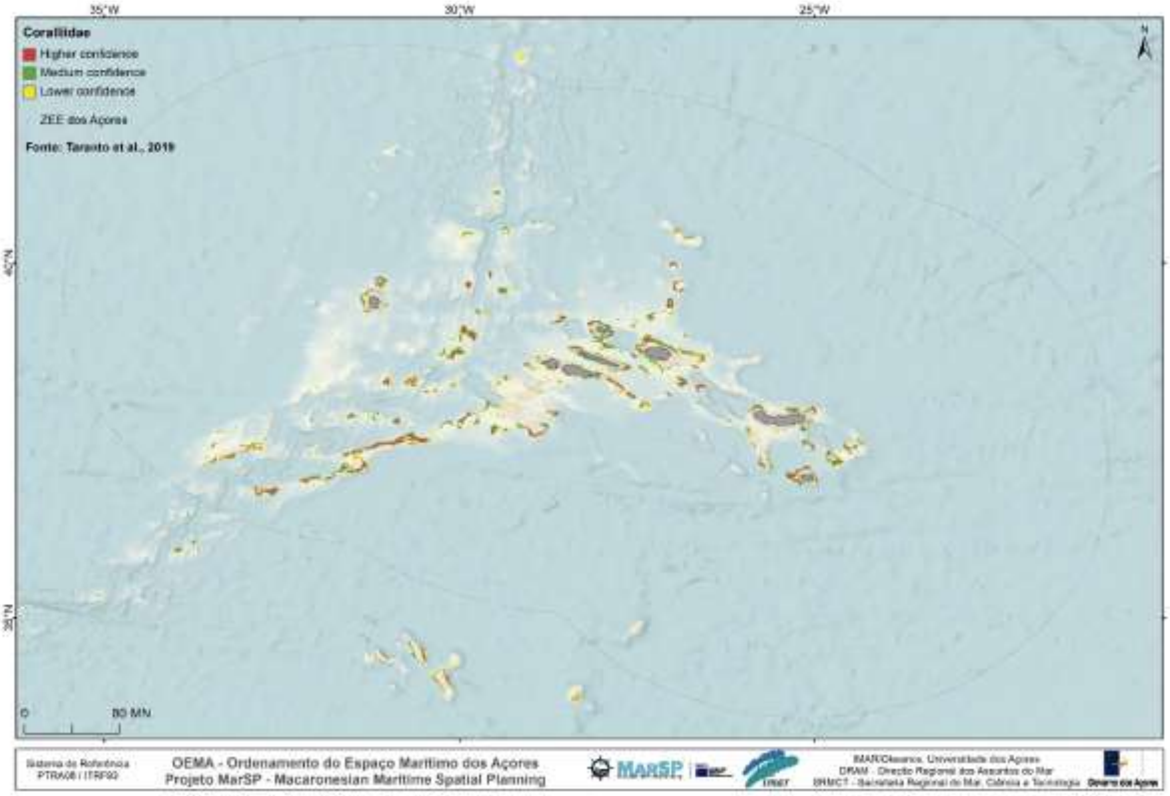
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral family Coralliidae. On this layer, there is the information about the predicted suitable habitat of the cold-water coral family Coralliidae.

Cold-water corals in the Azores: Coralliidae



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
WELL-KNOWN TEXT GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326

3.5.5. *Dentomuricea* aff. *meteor*

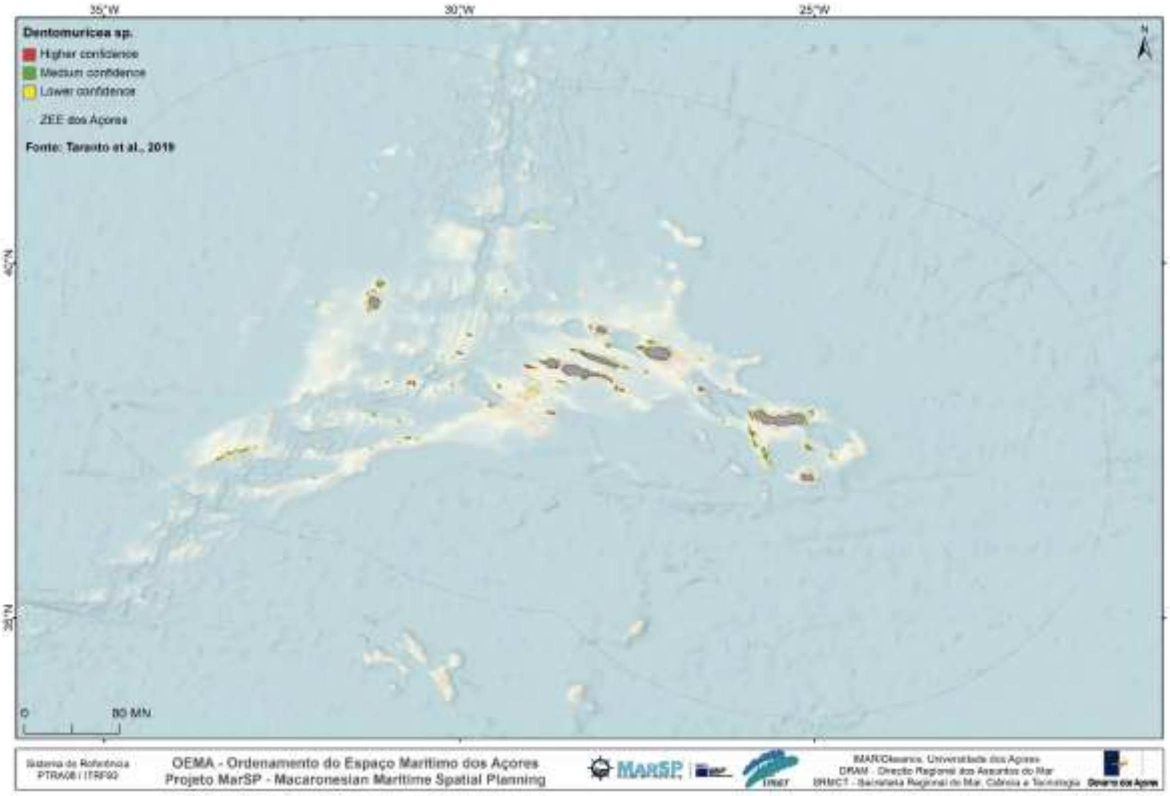
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Dentomuricea* aff. *meteor.* On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Dentomuricea* aff. *meteor.*

Cold-water corals in the Azores: *Dentomuricea* aff. *meteor*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

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North 43.141363 South 33.283892

Citation Contacts:
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

3.5.6. *Errina dabneyi*

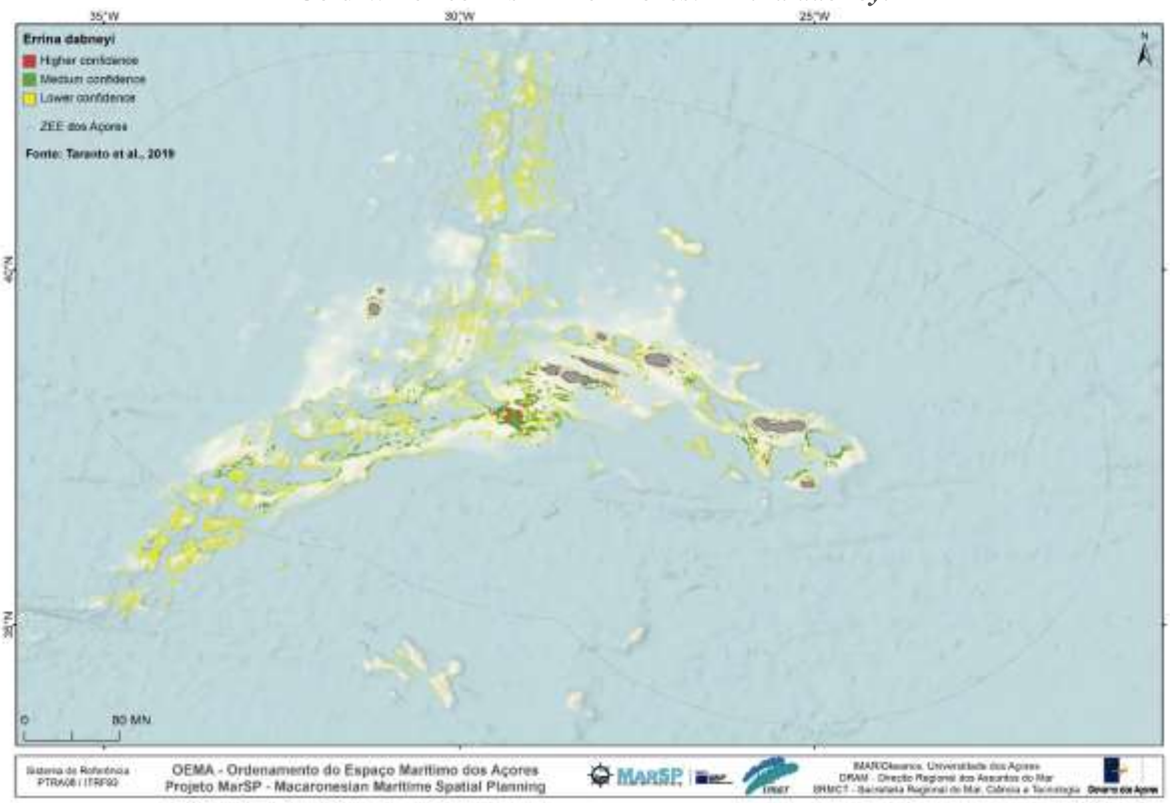
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Errina dabneyi*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Errina dabneyi*.

Cold-water corals in the Azores: *Errina dabneyi*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
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CONTACT'S ROLE Principal Investigator
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Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3.5.7. *Leiopathes* sp.

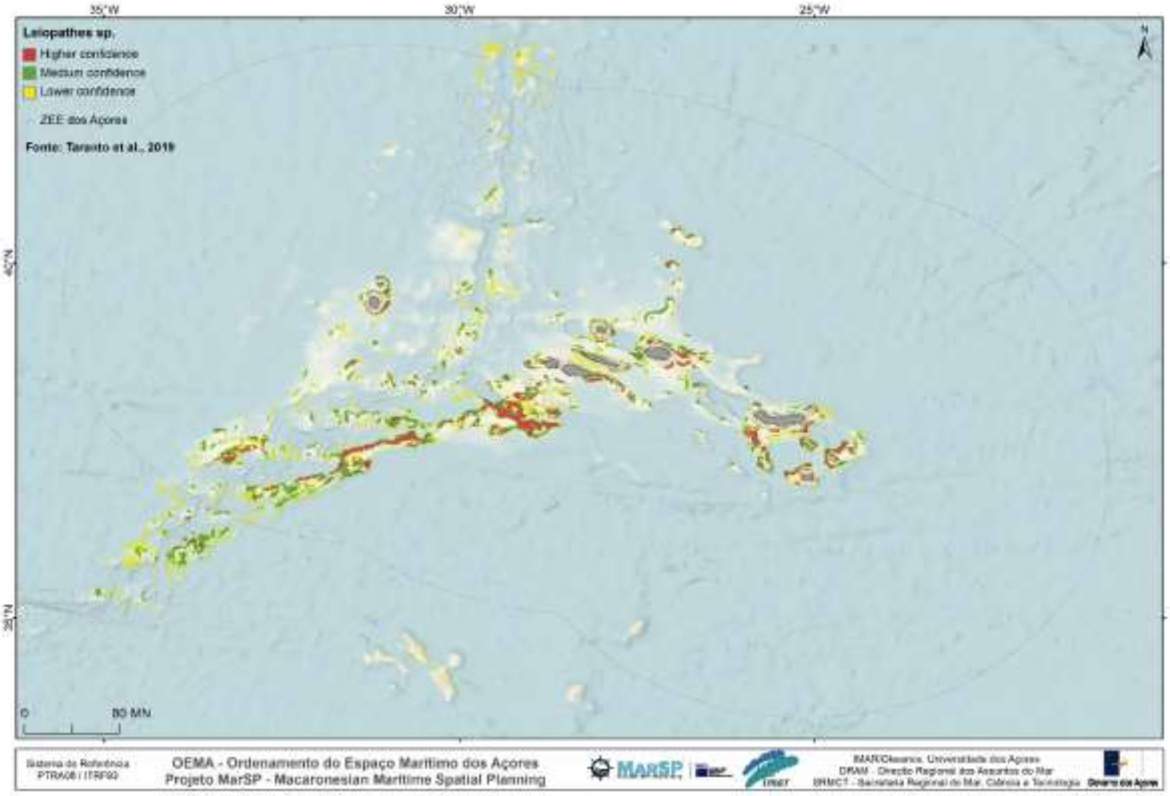
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral genus *Leiopathes*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral genus *Leiopathes*.

Cold-water corals in the Azores: *Leiopathes* sp.



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:

INDIVIDUAL'S NAME Gerald H. Taranto
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:

* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

3.5.8. *Lophelia pertusa*

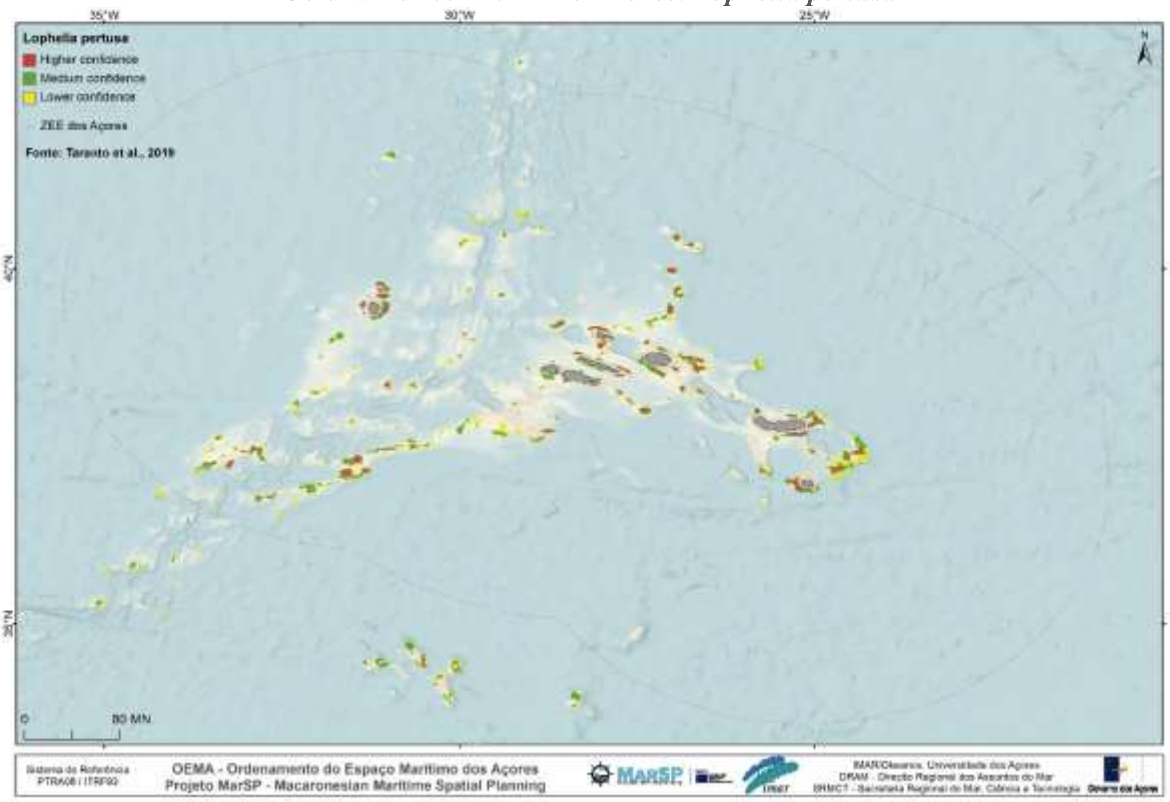
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Lophelia pertusa*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Lophelia pertusa*.

Cold-water corals in the Azores: *Lophelia pertusa*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
INDIVIDUAL'S NAME Gerald H. Taranto
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
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Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],AUTHORITY["EPSG",4326]]

3.5.9. *Madrepora oculata*

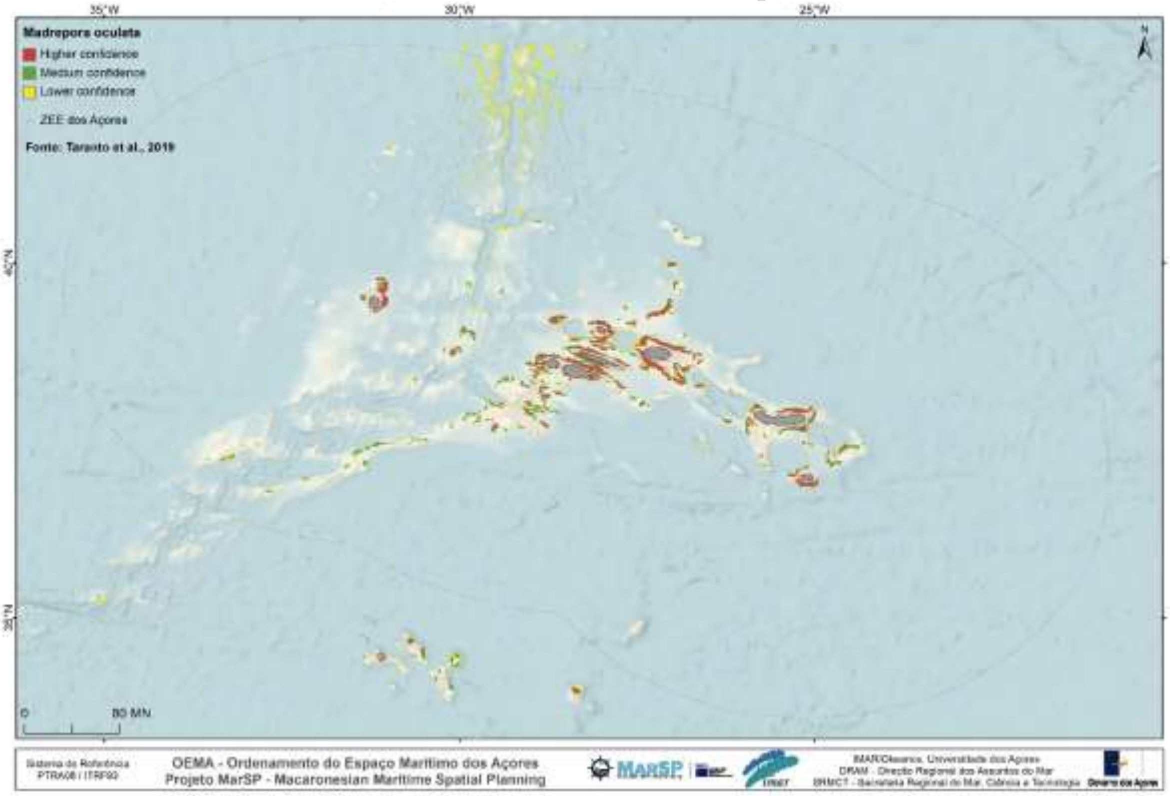
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Madrepora oculata*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Madrepora oculata*.

Cold-water corals in the Azores: *Madrepora oculata*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
INDIVIDUAL'S NAME Gerald H. Taranto
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
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E-MAIL ADDRESS gh.taranto@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
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CONTACT'S ROLE Principal Investigator
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Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

3.5.10. *Narella bellissima*

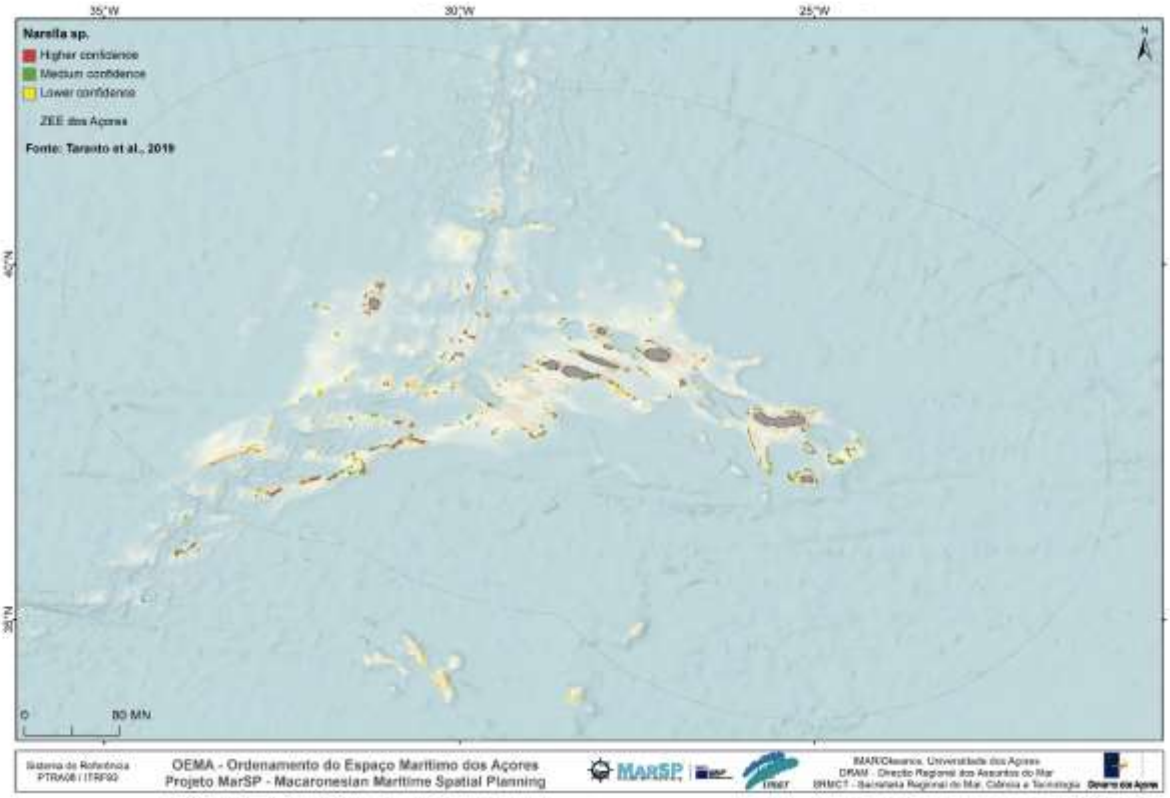
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Narella bellissima*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Narella bellissima*.

Cold-water corals in the Azores: *Narella bellissima*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
INDIVIDUAL'S NAME Gerald H. Taranto
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3.5.11. *Narella versluysi*

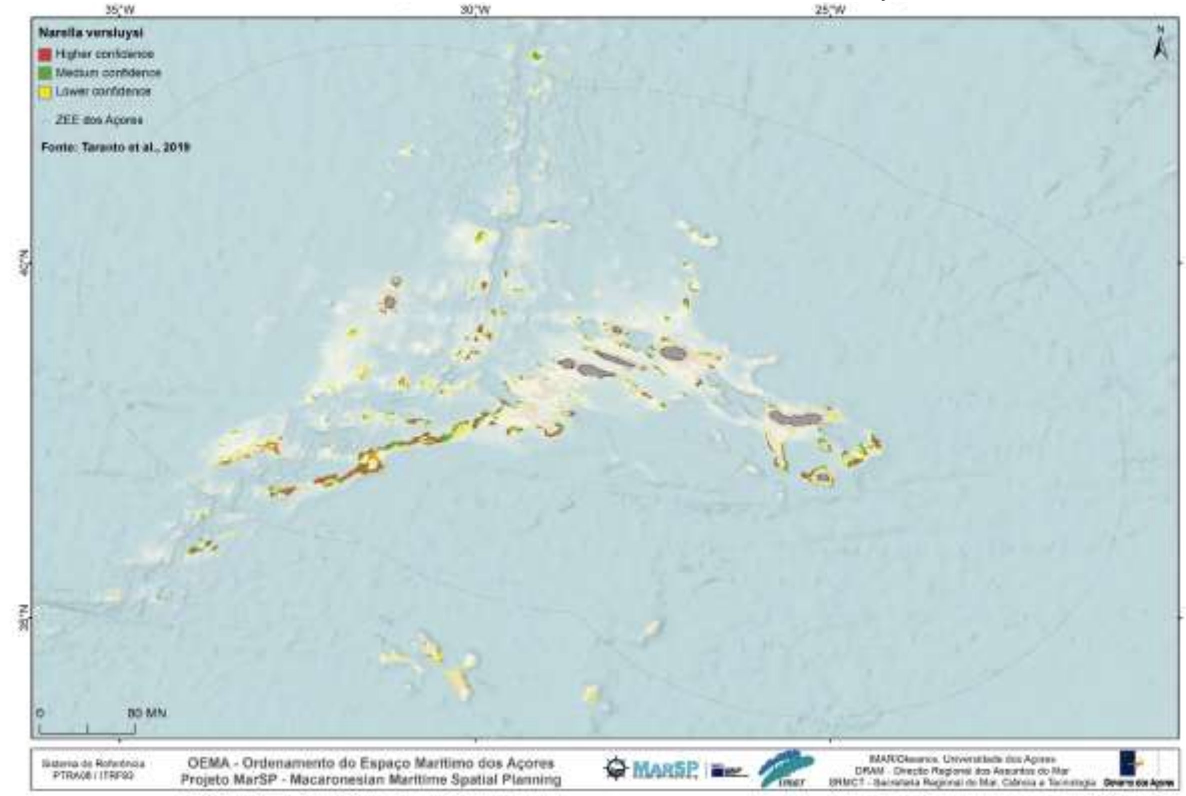
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Narella versluysi*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Narella versluysi*.

Cold-water corals in the Azores: *Narella versluysi*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.030847 East -20.285494

North 43.141363 South 33.283892

Citation Contacts:

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Spatial Reference:

* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true

Left longitude -180
Latest well-known identifier 4326

WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3.5.12. *Paracalyptrophora josephinae*

Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Paracalyptrophora josephinae*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Paracalyptrophora josephinae*.

Cold-water corals in the Azores: *Paracalyptrophora josephinae*

Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

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Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
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E-MAIL ADDRESS gh.taranto@gmail.com

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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3.5.13. *Paragorgia johnsoni*

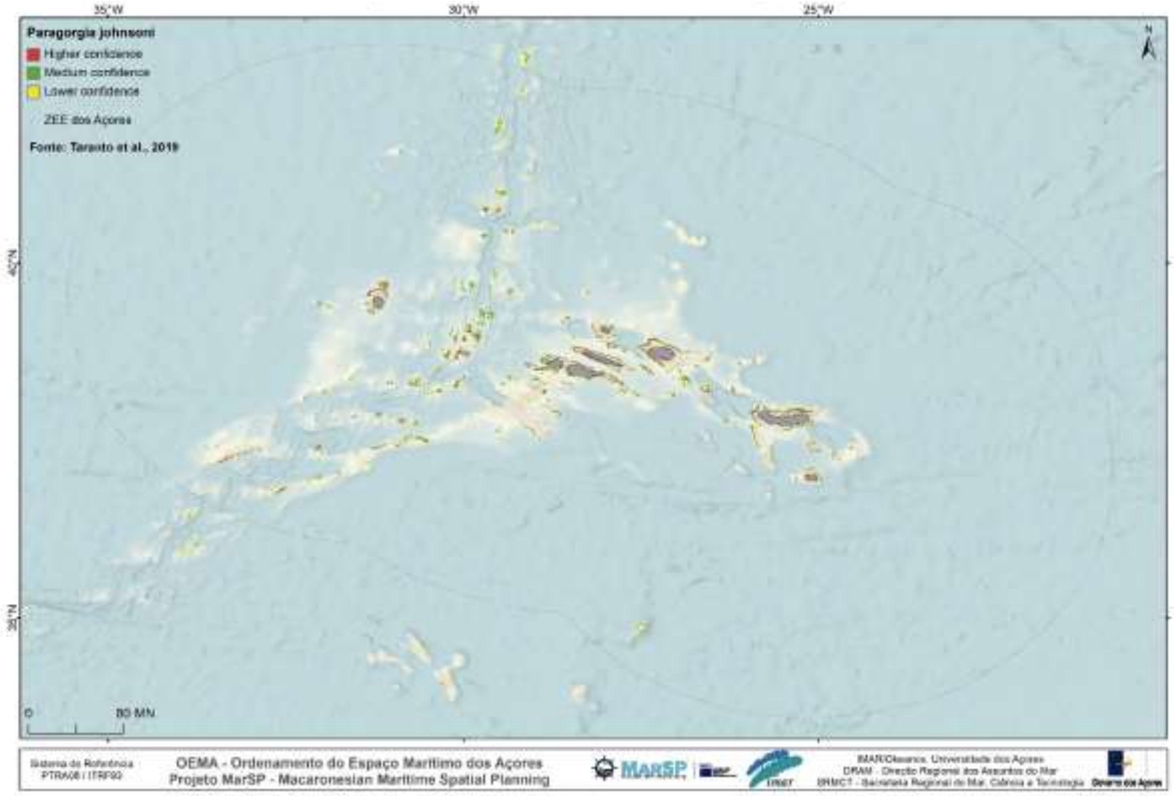
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Paragorgia johnsoni*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Paragorgia johnsoni*.

Cold-water corals in the Azores: *Paragorgia johnsoni*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.030847 East -20.285494

North 43.141363 South 33.283892

Citation Contacts:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001

M TOLERANCE 0.001

High precision true

WELL-KNOWN TEXT

GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180

Latest well-known identifier 4326

3.5.14. *Solenosmilia variabilis*

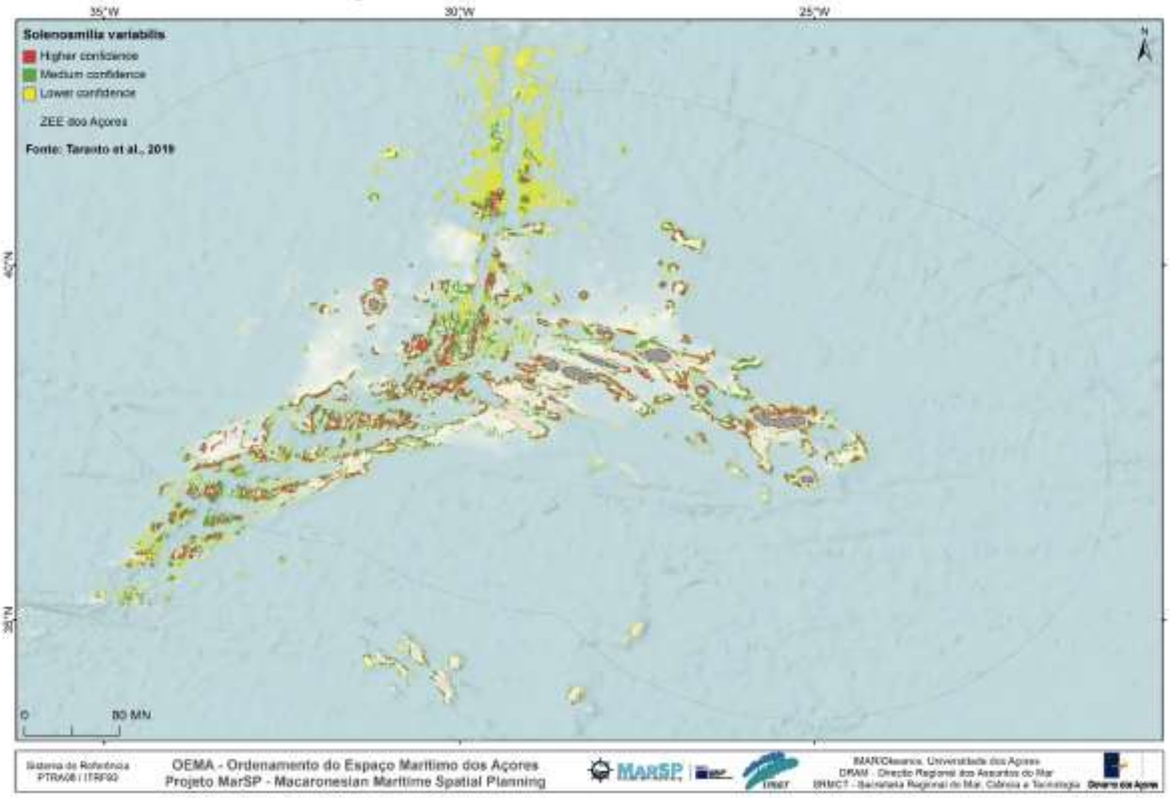
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Solenosmilia variabilis*. On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Solenosmilia variabilis.*

Cold-water corals in the Azores: *Solenosmilia variabilis*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.030847	East	-20.285494
North	43.141363	South	33.283892

Citation Contacts:
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

3.5.15. *Viminella flagellum*

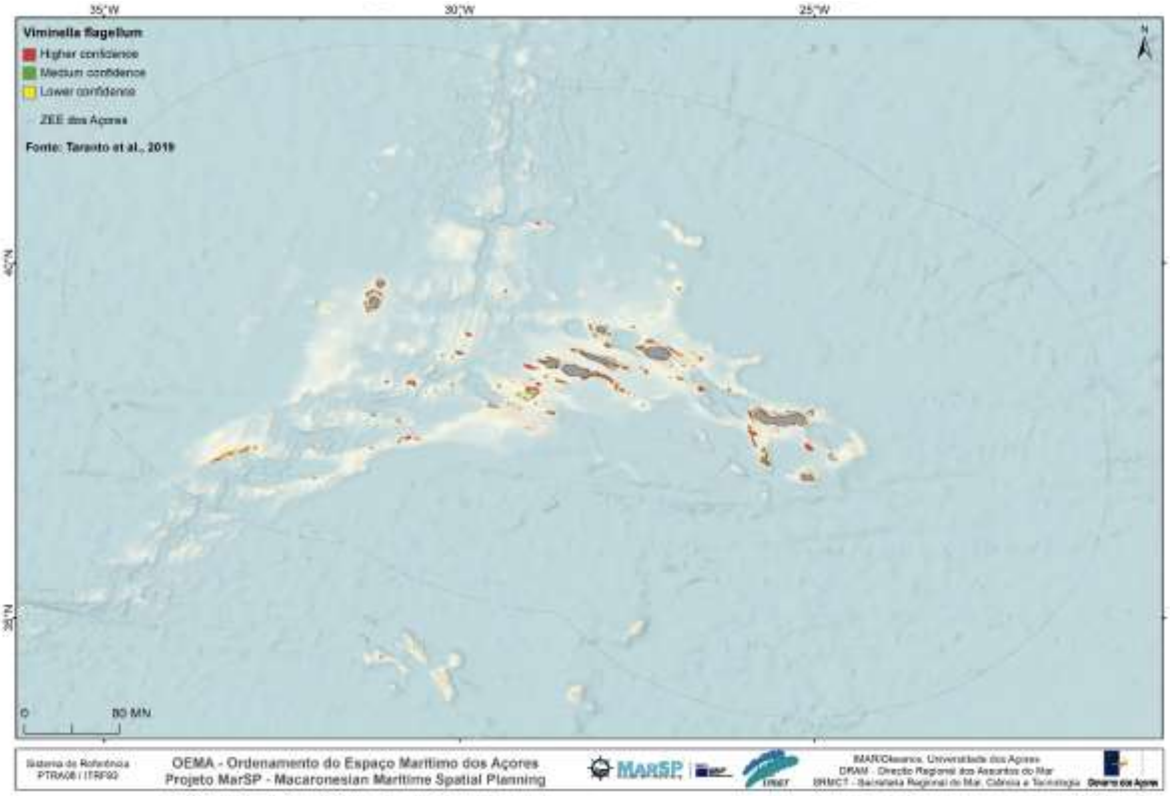
Raster Dataset: 1130m (4.17 MB)

Year: 2019

Keywords: Azores, EEZ Azores, Cold-water corals, Corals

Summary: This layer provides geographic information related to a predictive distribution modelling for cold-water coral species *Viminella flagellum.* On this layer, there is the information about the predicted suitable habitat of the cold-water coral species *Viminella flagellum*.

Cold-water corals in the Azores: *Viminella flagellum*



Credits: Atlas Project; IMAR/Okeanos. Universidade dos Açores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.030847 East -20.285494

North 43.141363 South 33.283892

Citation Contacts:
INDIVIDUAL'S NAME Gerald H. Taranto
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
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Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details Geographic coordinate system
Well-known identifier 4326
X ORIGIN -400
Y ORIGIN -400
XY SCALE 11258999068426.238
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Z SCALE 10000
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M SCALE 10000
XY TOLERANCE 8.983152841195215e-09

Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433],AUTHORITY["EPSG",4326]]

Left longitude -180
Latest well-known identifier 4326

3.6. Deep-water Sharks

Raster Dataset Series (15 models): 1120m (5.73 MB)

In this work, Generalized Additive Models (GAMs) were used to infer suitable habitat distribution of deep-sea elasmobranch species, which are occasionally caught as bycatch of the Azorean deep-sea hooks-and-line fisheries.

The goal of the study was to predict suitability habitats (probability of presence) of several species of deep-water sharks that can be used to achieve conservation and management objectives. In the process, we identified important drivers influencing the spatial distribution of these species, shedding light on their autecology for the first time for some of them.

To create this model, we used data from the fishery bottom longline between 1996 and 2017 onboard of the research vessel Arquipelago, from the national observer programme for discards (2004-2012 and 2016) and from the project Discardless (2017-18).

This Models of Deep-Water Sharks in the Azorean sea, has been developed inside the Atlas project, and it has been made by the researchers Diya Das, José Gonzalez-Irusta, Telmo Morato, Laurence Fauconnet, Claudia Viegas, Pedro Afonso, Alexandra Rosa, Diana Catarino and Eva Giacomello.

In this dataset, there are information about the probability of presence of the 15 species of deep-water sharks:

- *Centrophorus squamosus;*
- *Centroscymnus coelolepis;*
- *Centroscymnus owstonii;*
- *Centroselachus crepidater;*
- *Dalatias licha;*
- *Deania calcea;*
- *Deania profundorum;*
- *Dipturus batis;*
- *Etmopterus princeps;*
- *Etmopterus pusillus;*
- *Etmopterus spinax;*
- *Galeorhinus galeus;*
- *Leucoraja fullonica;*
- *Raja clavata;*
- *Squaliolus laticaudus*.

3.6.1. *Centrophorus squamosus*

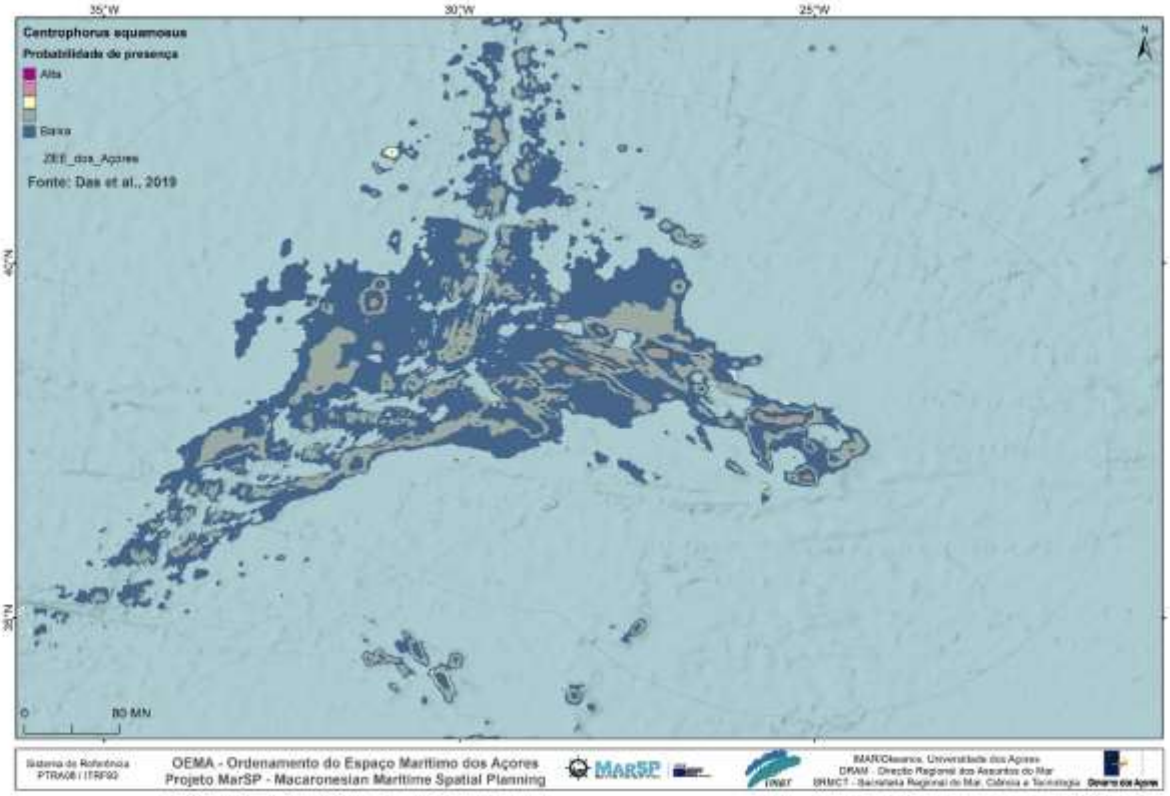
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Centrophorus squamosus* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Centrophorus squamosus*.

Deep-water sharks in the Azores: *Centrophorus squamosus*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: “Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
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CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
WELL-KNOWN TEXT
PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

3.6.2. *Centroscymnus coelolepis*

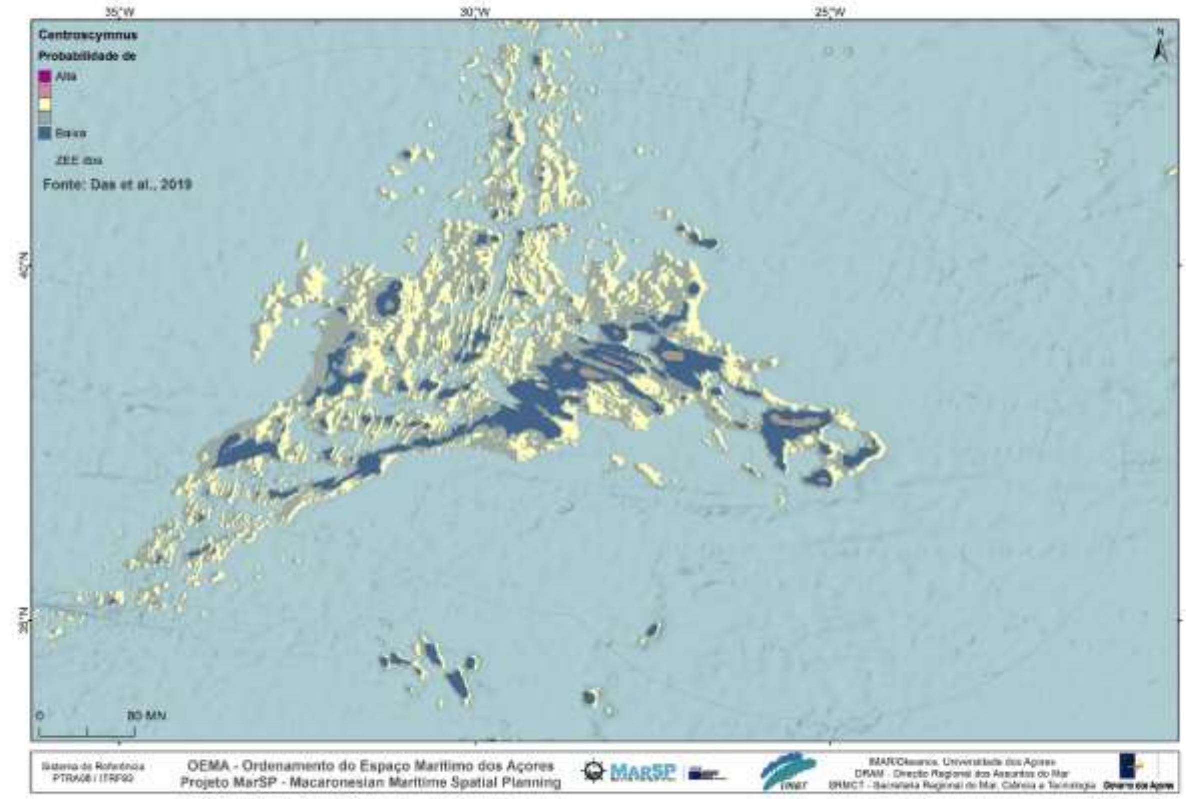
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Centroscymnus coelolepis* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Centroscymnus coelolepis*.

Deep-water sharks in the Azores: *Centroscymnus coelolepis*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: “Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
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CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001

High precision true Latest well-known identifier 32626

WELL-KNOWN TEXT

PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984", SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree", 0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

3.6.3. *Centroscymnus owstonii*

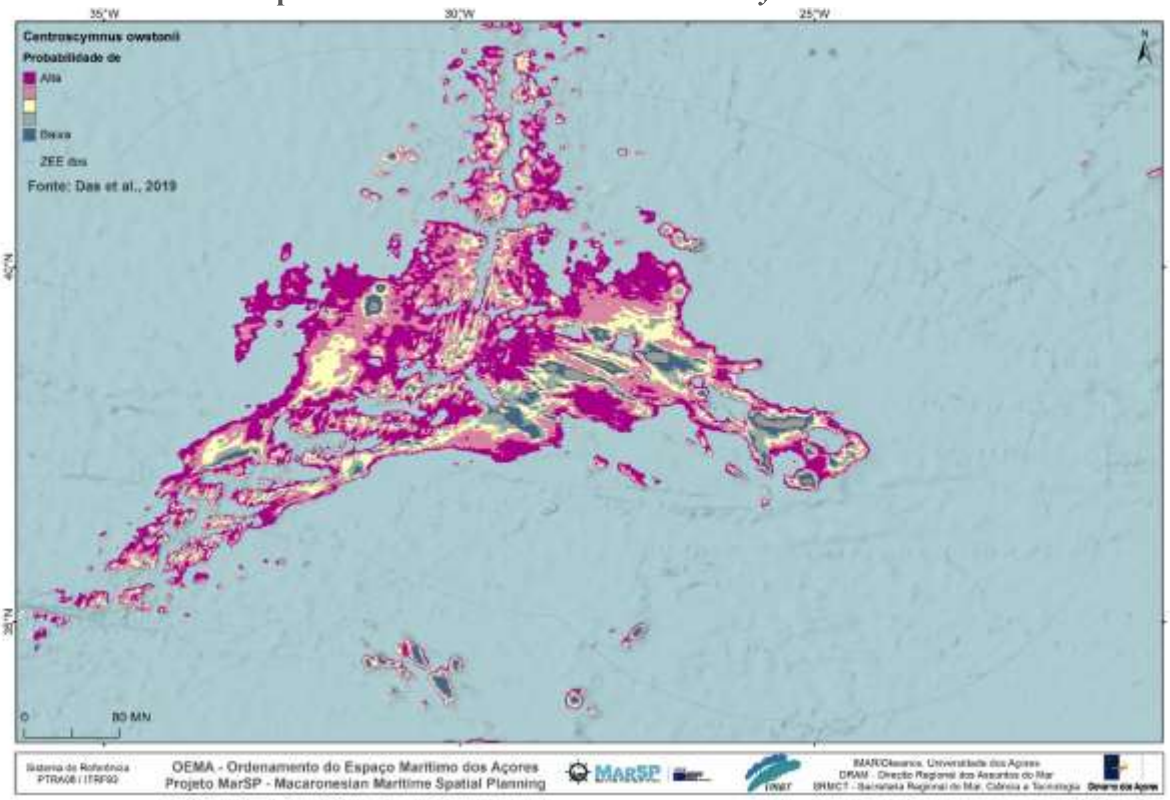
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Centroscymnus owstonii* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Centroscymnus owstonii*.

Deep-water sharks in the Azores: *Centroscymnus owstonii*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -37.479533 East -18.832939

North 44.355782 South 32.678347

Citation Contacts:
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CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
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Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
WELL-KNOWN TEXT
PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984", SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree", 0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

3.6.4. *Centroselachus crepidater*

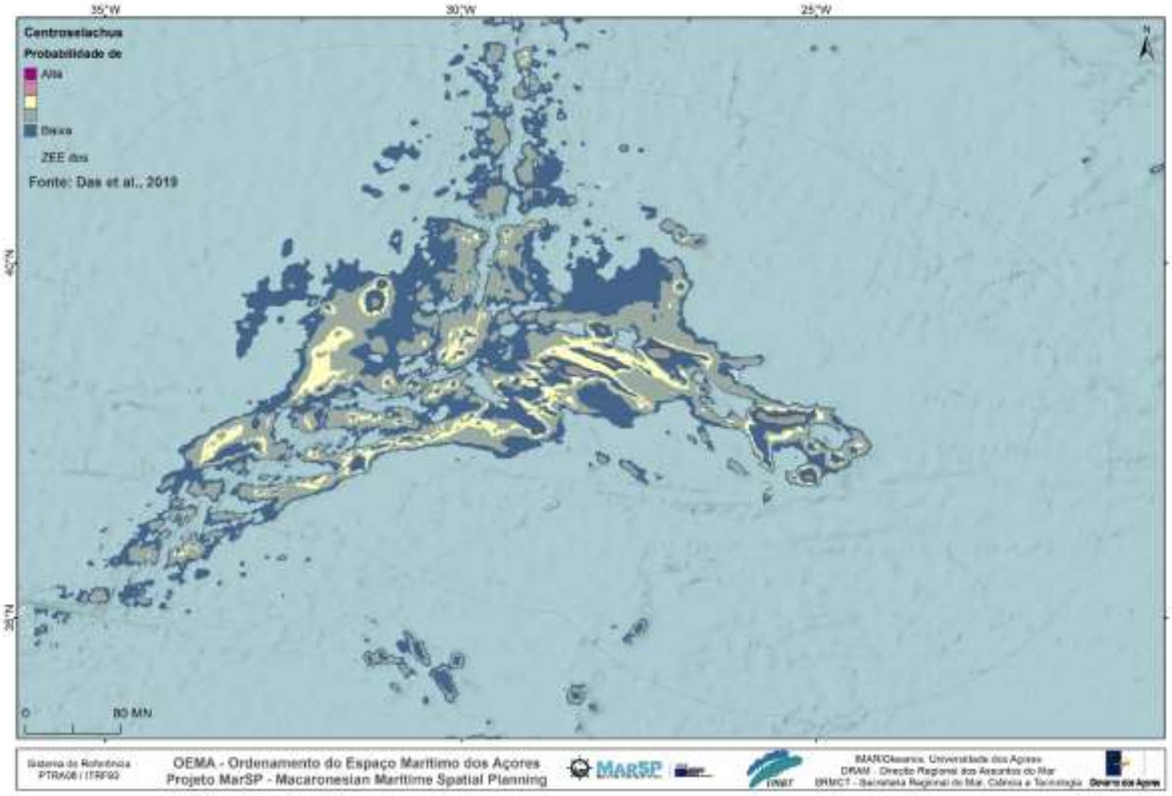
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Centrophorus crepidater* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Centrophorus crepidater*.

Deep-water sharks in the Azores: *Centroselachus crepidater*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: “Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
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CONTACT’S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001

M TOLERANCE 0.001

Latest well-known identifier 32626

High precision true

WELL-KNOWN TEXT

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3.6.5. *Dalatias licha*

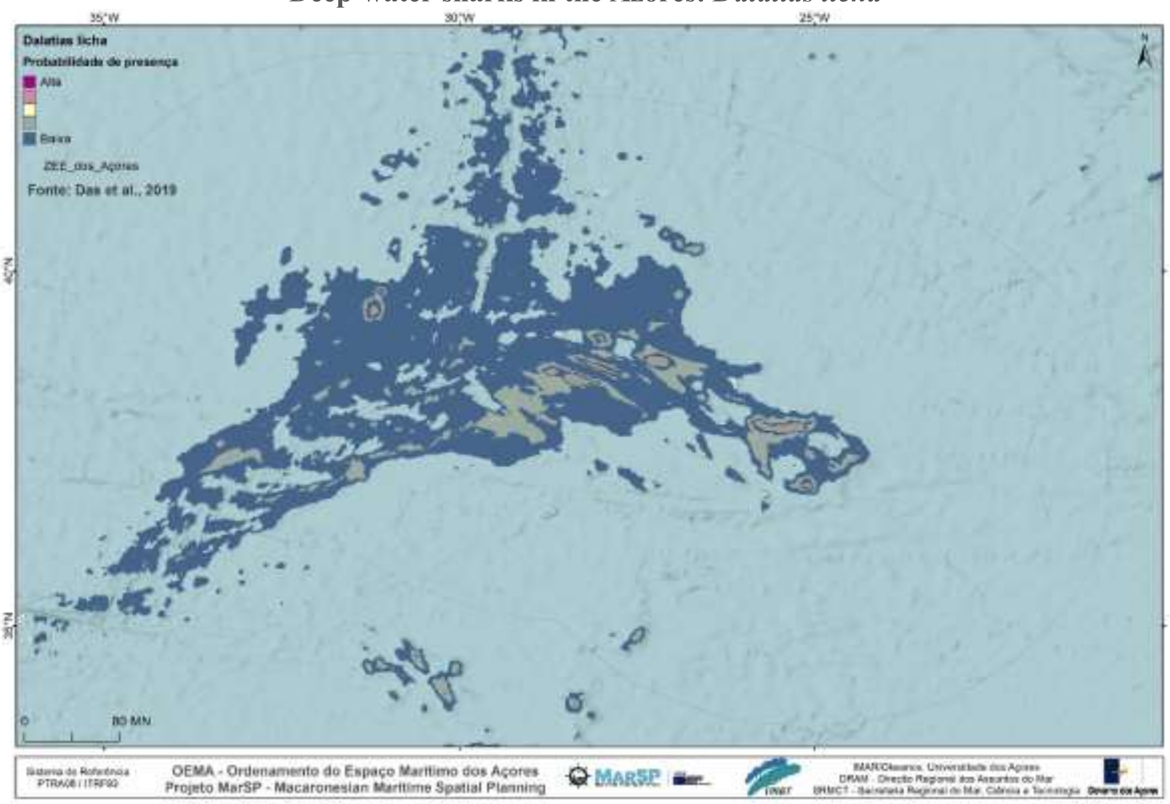
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Dalatias licha* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Dalatias licha*.

Deep-water sharks in the Azores: *Dalatias licha*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -37.479533 East -18.832939

North 44.355782 South 32.678347

Citation Contacts:

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CONTACT'S ROLE Principal Investigator

E-MAIL ADDRESS diyadas.d@gmail.com

Point of Contact:

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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores

CONTACT'S POSITION Geospatial Data Scientist

CONTACT'S ROLE Principal Investigator

Spatial Reference:

* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details

Projected coordinate system

Well-known identifier 32626

X ORIGIN -5120900

Y ORIGIN -9998100

XY SCALE 450445547.3910538

Z ORIGIN -100000

Z SCALE 10000

M ORIGIN -100000

M SCALE 10000

XY TOLERANCE 0.001

Z TOLERANCE 0.001

M TOLERANCE 0.001

High precision true

Latest well-known identifier 32626

WELL-KNOWN TEXT

PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984", SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree", 0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

3.6.6. *Deania calcea*

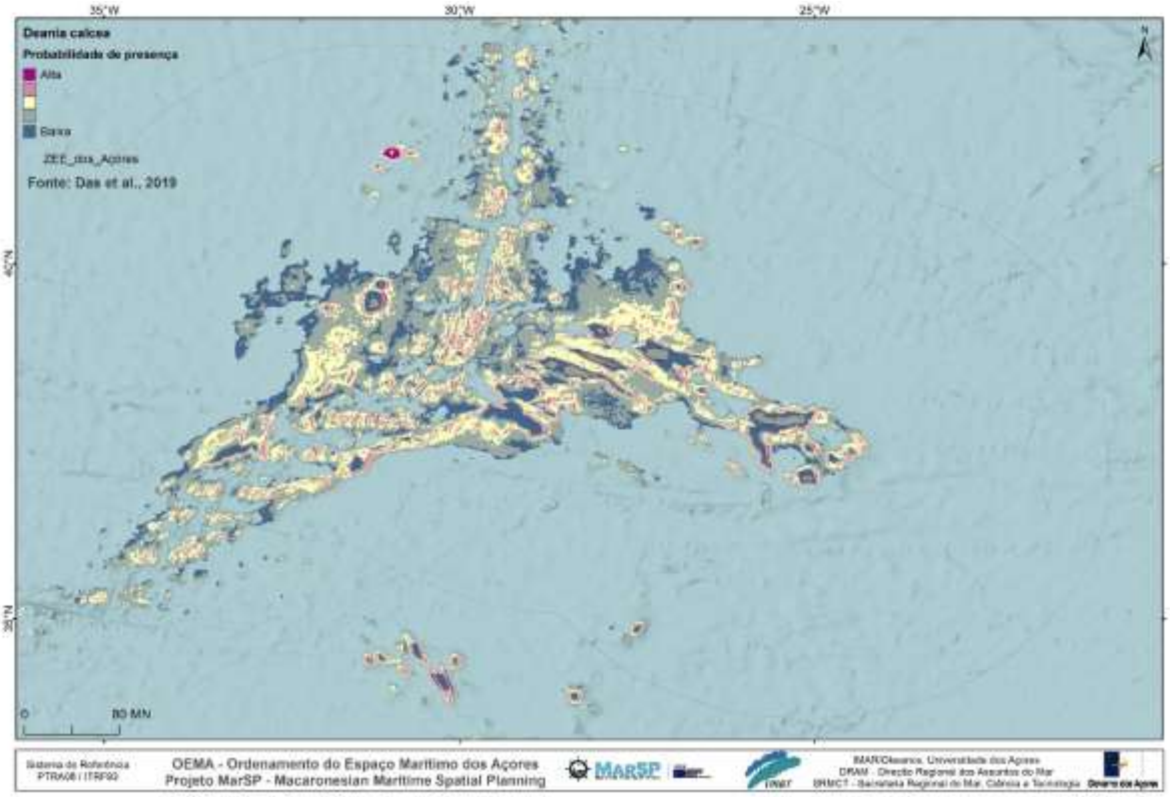
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Deania calcea* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Deania calcea*.

Deep-water sharks in the Azores: *Deania calcea*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
INDIVIDUAL'S NAME Diya Das
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS diyadas.d@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001

M TOLERANCE 0.001 Latest well-known identifier 32626
High precision true
WELL-KNOWN TEXT
PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

3.6.7. *Deania profundorum*

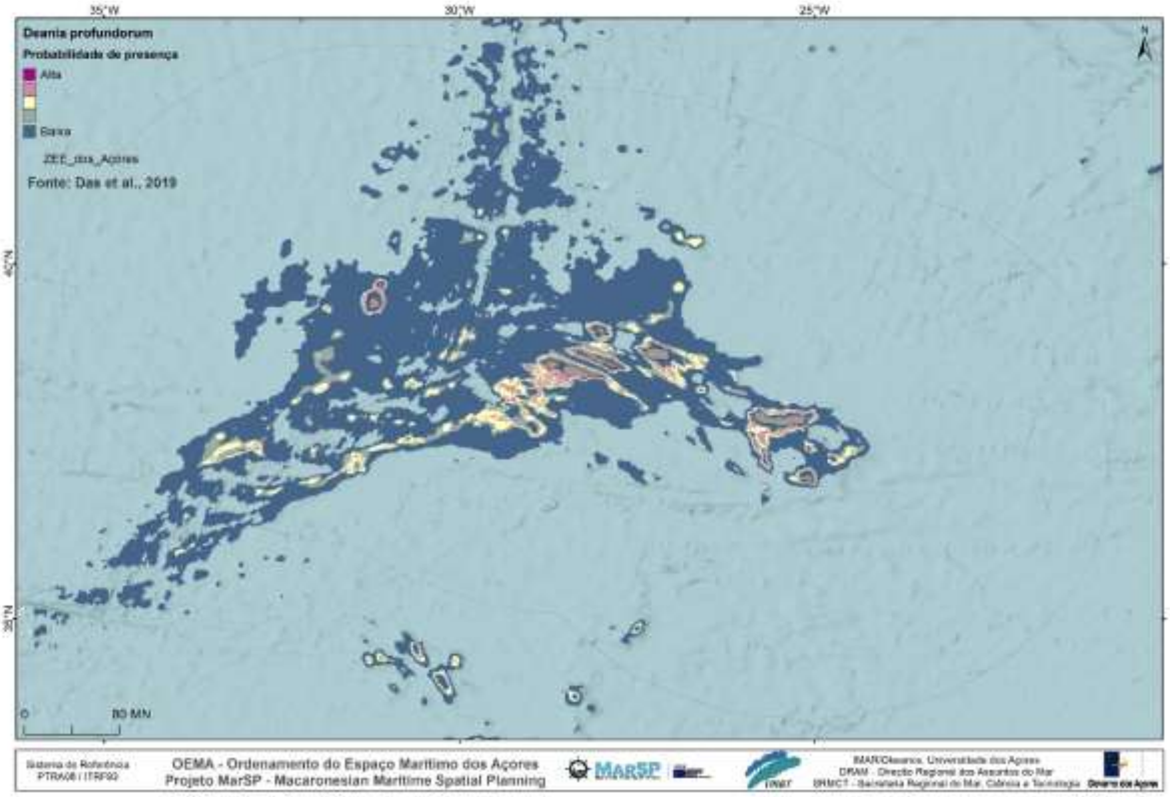
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Deania profundorum* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Deania profundorum*.

Deep-water sharks in the Azores: *Deania profundorum*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -37.479533 East -18.832939
North 44.355782 South 32.678347

Citation Contacts:
INDIVIDUAL'S NAME Diya Das
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS diyadas.d@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
WELL-KNOWN TEXT
PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

3.6.8. *Dipturus batis*

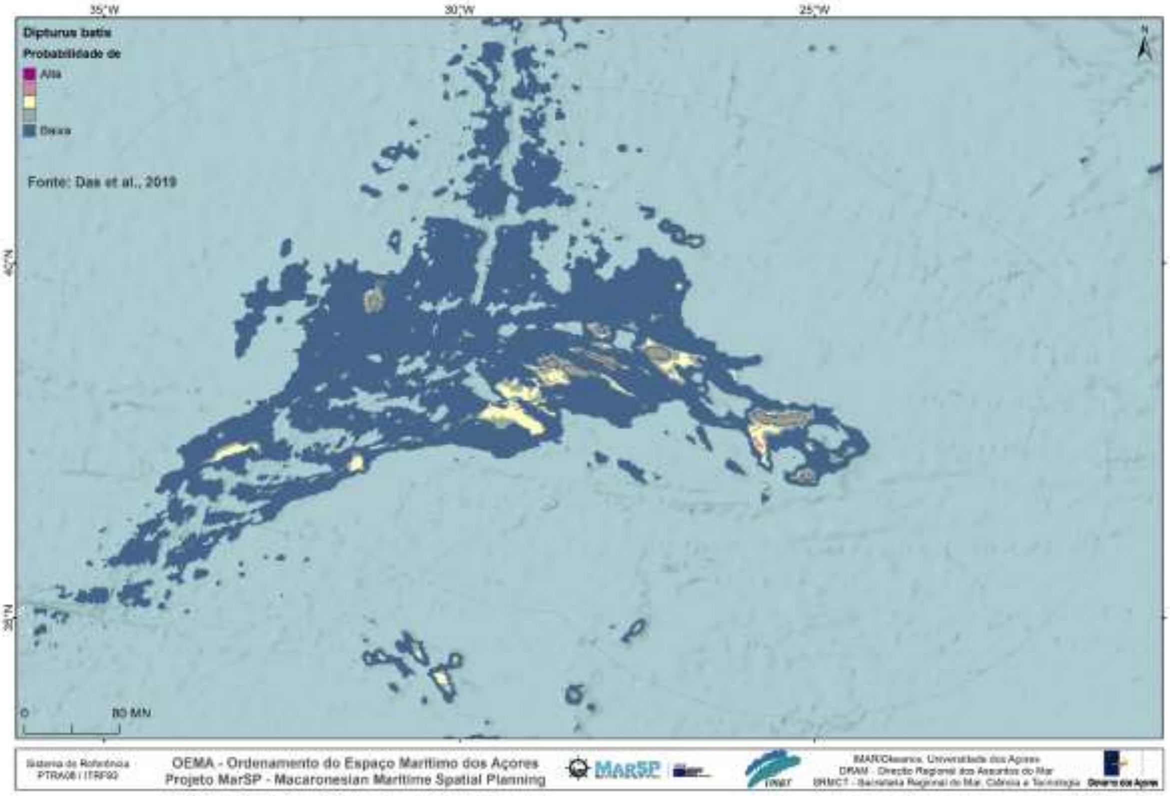
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Dipturus batis* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Dipturus batis*.

Deep-water sharks in the Azores: *Dipturus batis*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: “Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
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Point of Contact:
INDIVIDUAL’S NAME Luis Rodrigues
ORGANIZATION’S NAME IMAR/Okeanos. University of the Azores
CONTACT’S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator

Spatial Reference:
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* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
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Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
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M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001

M TOLERANCE 0.001 Latest well-known identifier 32626
High precision true
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3.6.9. *Etmopterus princeps*

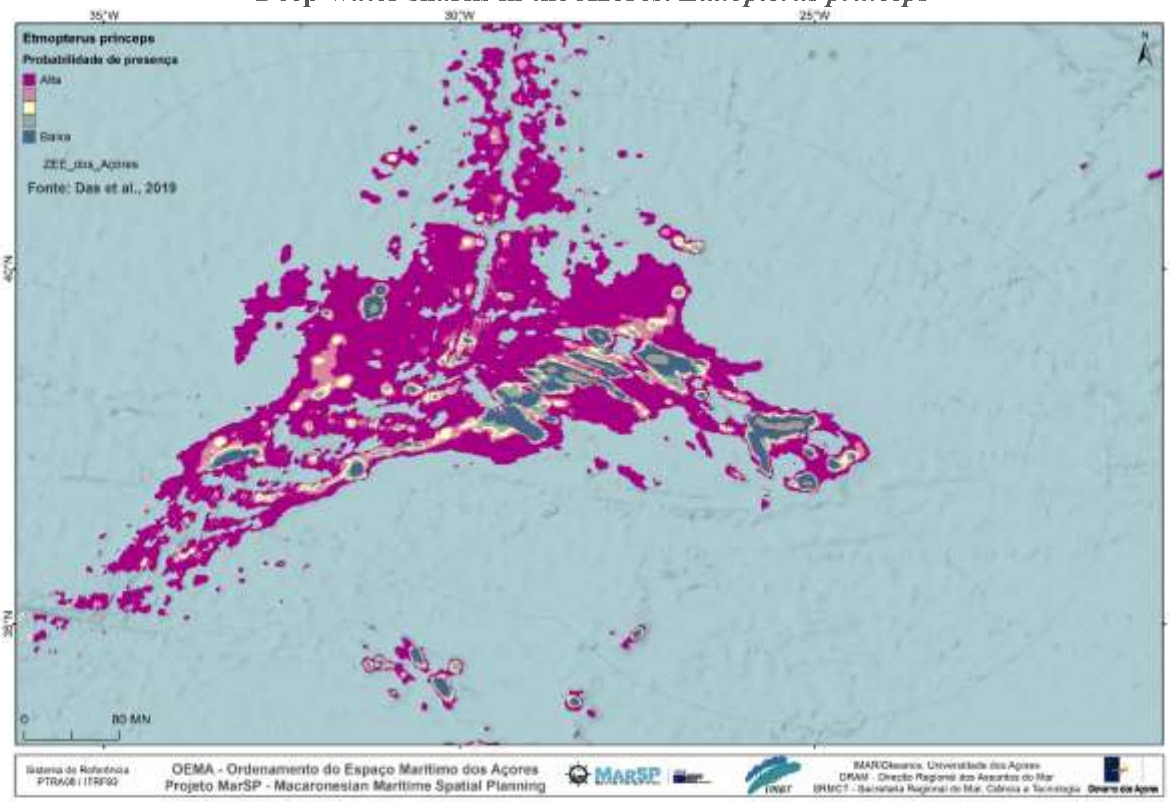
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Etmopterus princeps* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Etmopterus princeps*.

Deep-water sharks in the Azores: *Etmopterus princeps*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -37.479533 East -18.832939
North 44.355782 South 32.678347

Citation Contacts:
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Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
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XY SCALE 450445547.3910538
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Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
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M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
WELL-KNOWN TEXT
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3.6.10. *Etmopterus pusillus*

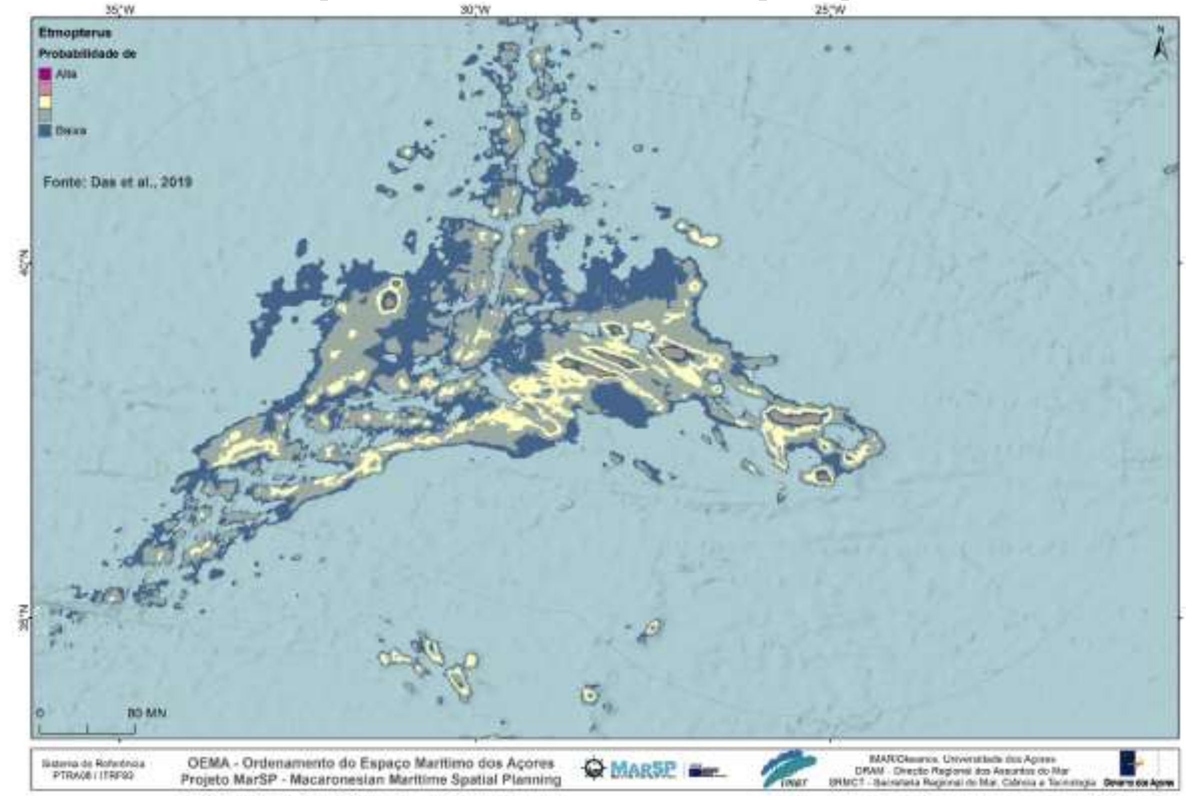
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Etmopterus pusillus* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Etmopterus pusillus*.

Deep-water sharks in the Azores: *Etmopterus pusillus*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: “Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
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CONTACT'S ROLE Principal Investigator

Spatial Reference:
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* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
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Well-known identifier 32626
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M SCALE 10000
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Z TOLERANCE 0.001

M TOLERANCE 0.001 Latest well-known identifier 32626
High precision true
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3.6.11. *Etmopterus spinax*

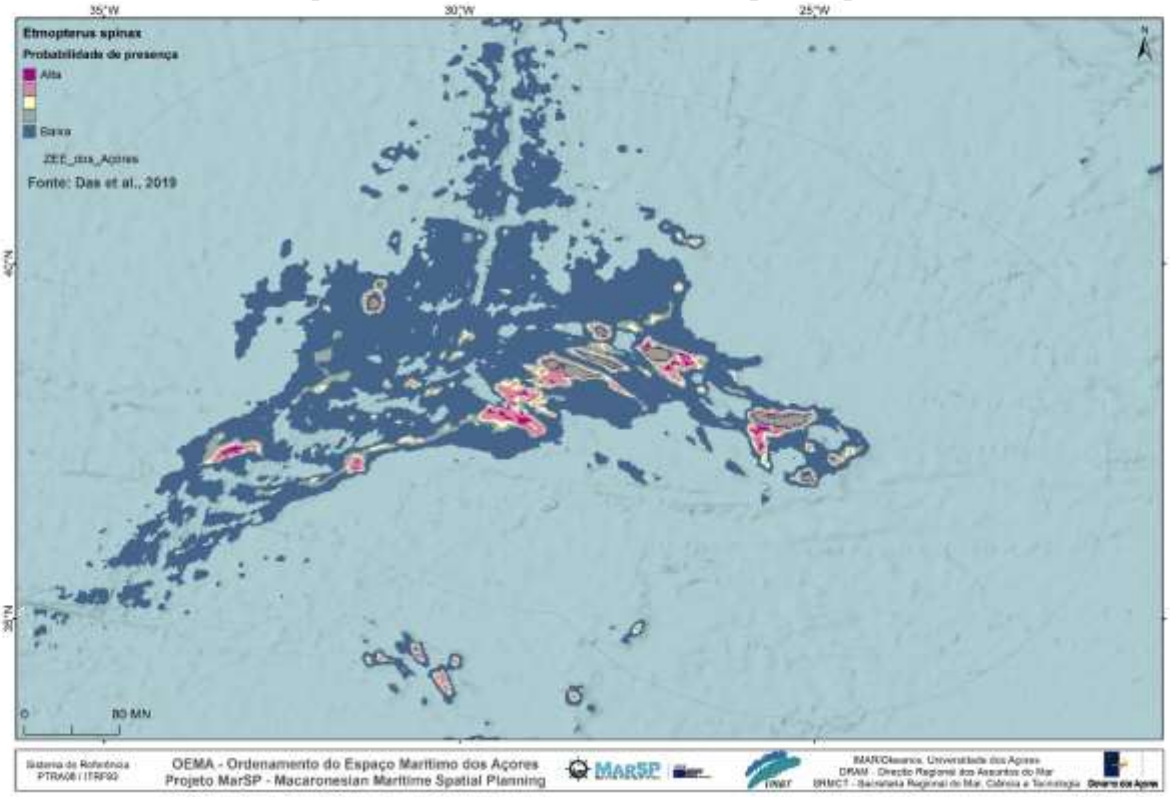
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Etmopterus spinax* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Etmopterus spinax*.

Deep-water sharks in the Azores: *Etmopterus spinax*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -37.479533 East -18.832939
North 44.355782 South 32.678347

Citation Contacts:
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CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
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* PROJECTION WGS_1984_UTM_Zone_26N
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Projected coordinate system
Well-known identifier 32626
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M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
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3.6.12. *Galeorhinus galeus*

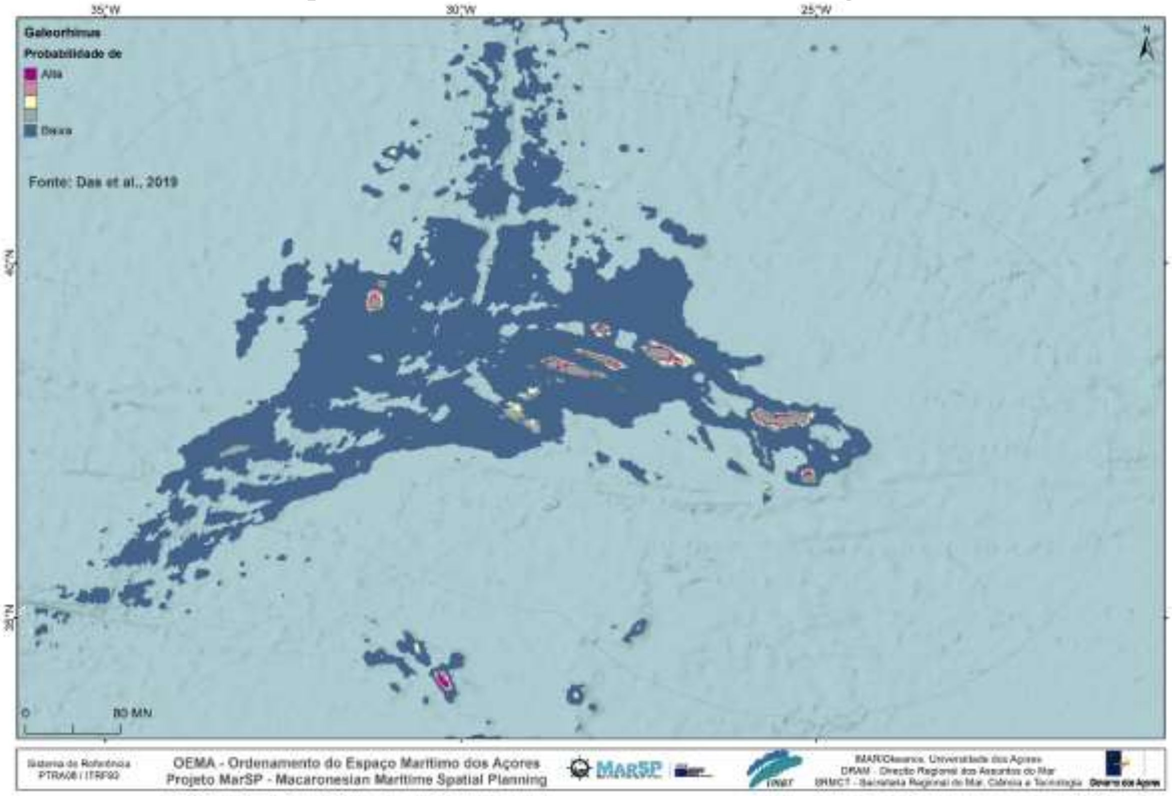
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Galeorhinus galeus* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Galeorhinus galeus*.

Deep-water sharks in the Azores: *Galeorhinus galeus*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: “Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
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E-MAIL ADDRESS diyadas.d@gmail.com

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CONTACT'S ROLE Principal Investigator

Spatial Reference:
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* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
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Projected coordinate system
Well-known identifier 32626
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Z SCALE 10000
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M SCALE 10000
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M TOLERANCE 0.001 Latest well-known identifier 32626
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3.6.13. *Leucoraja fullonica*

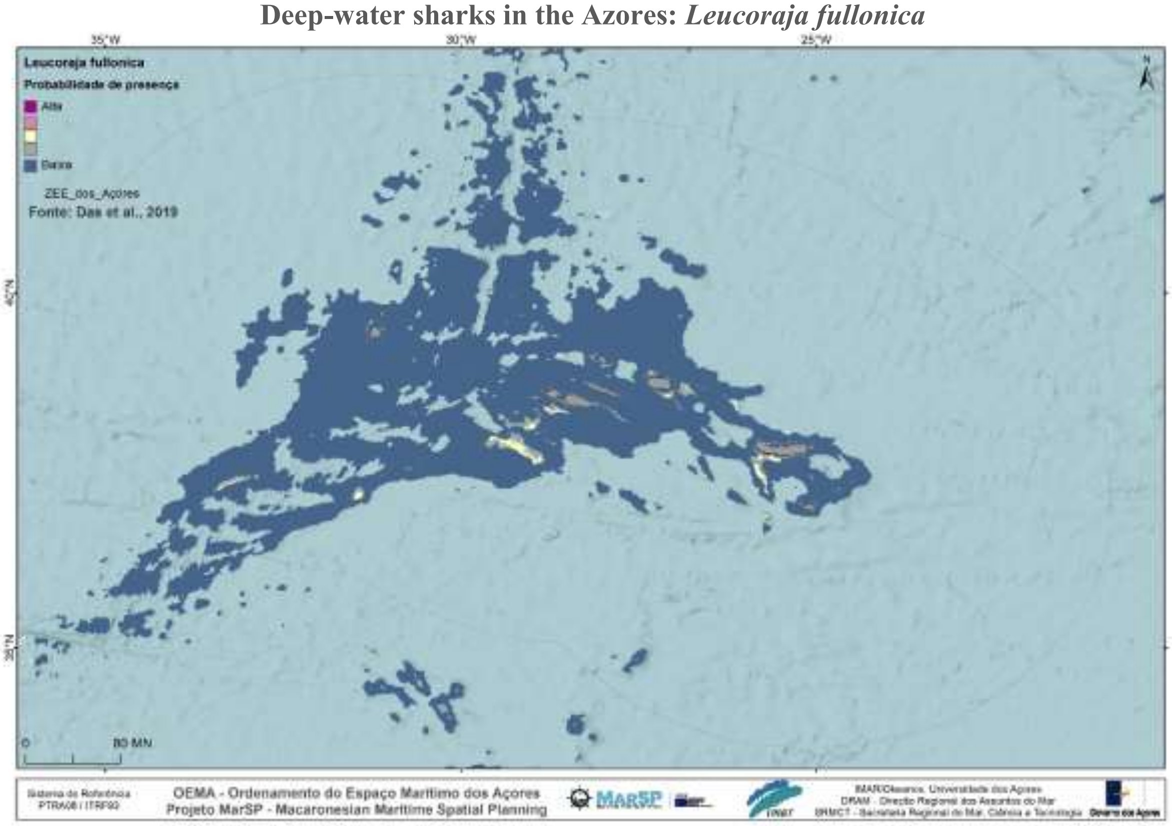
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Leucoraja fullonica* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Leucoraja fullonica*.

Deep-water sharks in the Azores: *Leucoraja fullonica*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -37.479533 East -18.832939

North 44.355782 South 32.678347

Citation Contacts:
INDIVIDUAL'S NAME Diya Das
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS diyadas.d@gmail.com

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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
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Projected coordinate system
Well-known identifier 32626
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Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
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Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
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3.6.14. *Raja clavata*

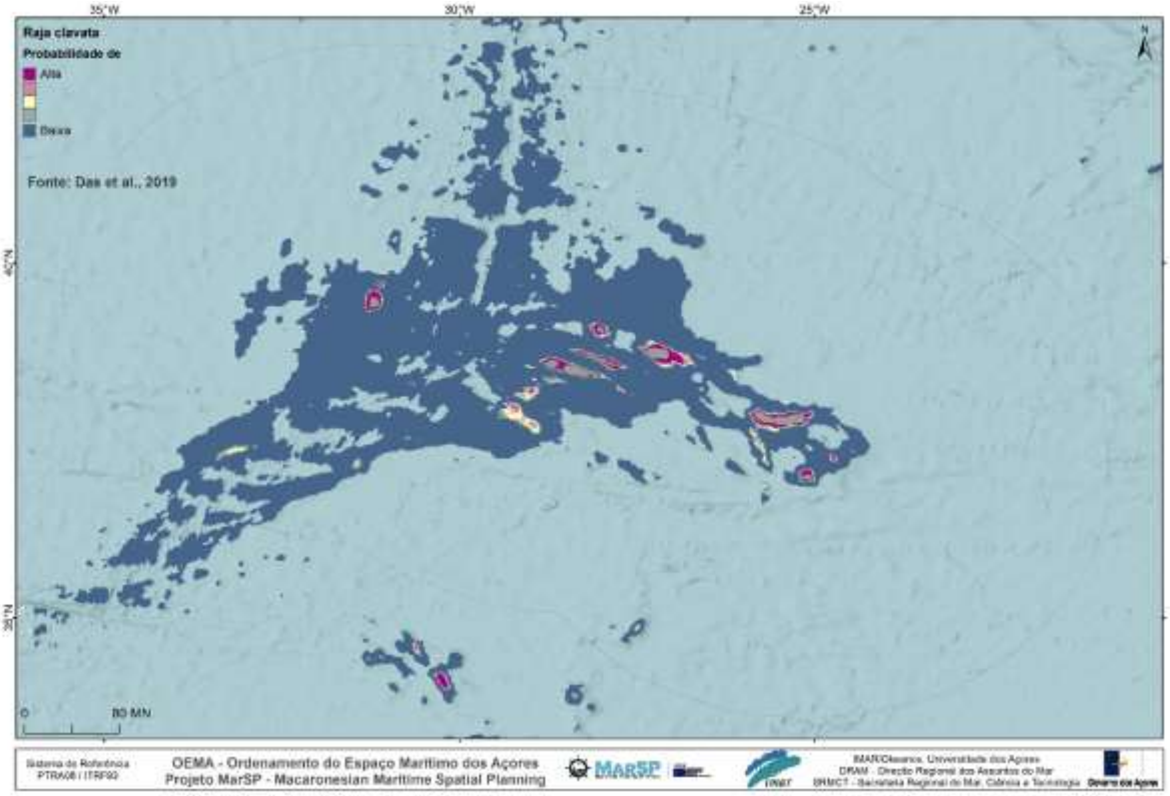
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Raja clavata* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Raja clavata*.

Deep-water sharks in the Azores: *Raja clavata*



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
INDIVIDUAL'S NAME Diya Das
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS diyadas.d@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
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XY SCALE 450445547.3910538
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Z SCALE 10000
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Z TOLERANCE 0.001

M TOLERANCE 0.001 Latest well-known identifier 32626
High precision true
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3.6.15. *Squaliolus laticaudus*

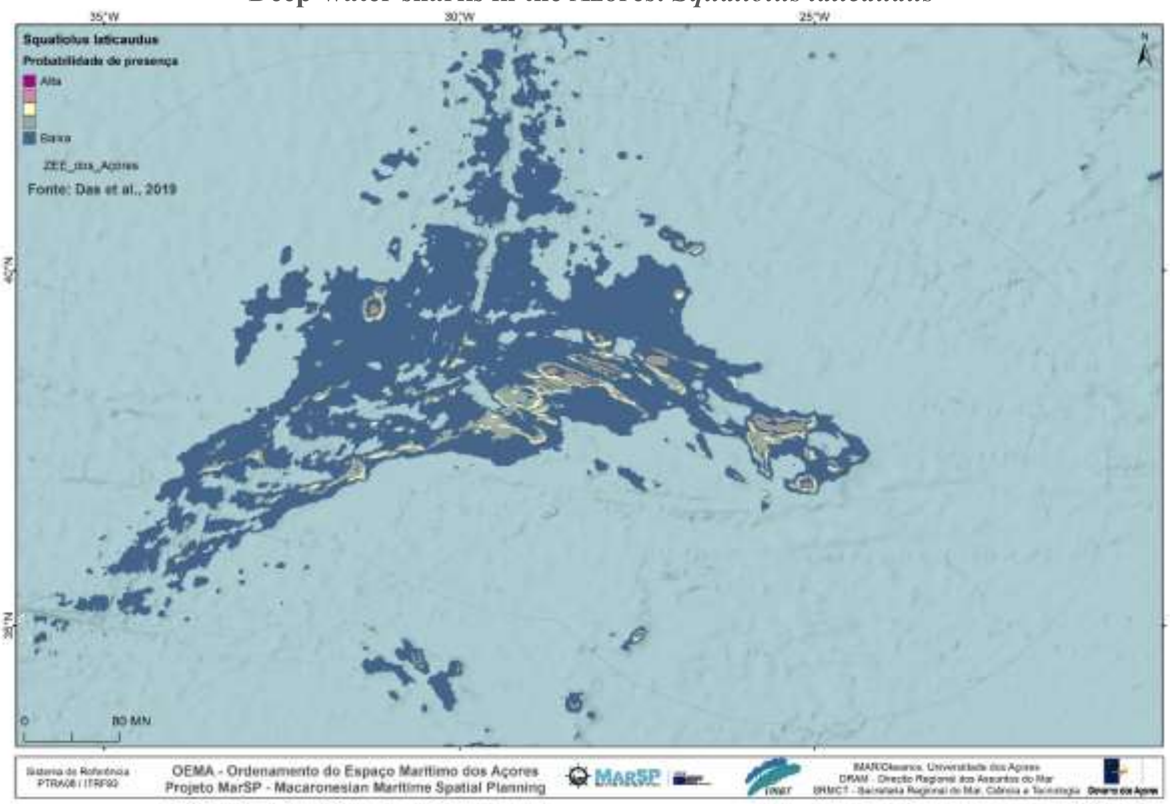
Raster Dataset: 1120m (5.73 MB)

Year: 2019

Keywords: Species distribution modelling, suitable habitat, deep sea elasmobranchs, generalised additive models, delta GAMs, North Atlantic, Mid-Atlantic Ridge, Azores

Summary: This layer provides geographic information related to predict suitability habitats (probability of presence) of *Squaliolus laticaudus* (deep-water shark) and eventually identify their hotspots of diversity and abundance. In this layer, there is information about the probability of presence of the deep-water shark *Squaliolus laticaudus*.

Deep-water sharks in the Azores: ***Squaliolus laticaudus***



Credits: Atlas Project; Discardless Project. IMAR/Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.479533	East	-18.832939
North	44.355782	South	32.678347

Citation Contacts:
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS diyadas.d@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
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Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
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3.7. Fish Species Predictive Distribution Modelling

Predictive Distribution Modelling is an innovative GIS-based method used to produce predictive maps of where elements (species, ecological community type) are likely to occur and likely to not occur. The probability of occurrence is quantified and is directly related to underlying environmental variables and the locations of known occurrences.

3.7.1. Fish Species Presence Predictive Distribution Modelling

Raster Dataset Series (8 Models): 339.5m (92.13MB)

On this raster, models were constructed based on fish occurrence and abundance data gathered from 13 years of bottom longline surveys (470 sets between 1996 and 2011, with the exception of 1998 and 2006, on the research vessel "Arquipélago"), combined with fine scale derived seafloor variables (water column depth, sediment type, bottom slope and aspect, converted into eastness and northness).

(Extracted from "Spatial Prediction of demersal fish species presence and abundance in the Azores", Hugo Parra et al., 2017).

In this dataset, there are information about presence-absence distribution models of the 8 fish species:

- *Phycis phycis* / Forkbeard;
- *Beryx splendens* / Splendid alfonsino;
- *Pontinus kuhlii* / Offshore rockfish;
- *Helicolenus dactylopterus* / Blackbelly rosefish;
- *Polyprion americanus* / Wreckfish;
- *Pagellus bogaraveo* / Red sea bream;
- *Beryx decadactylus* / Imperador;
- *Pagrus pagrus* / Red porgy.

3.7.1.1. Presence of *Phycis phycis /* Forkbeard

Raster Dataset: 339.5m (5.76MB)

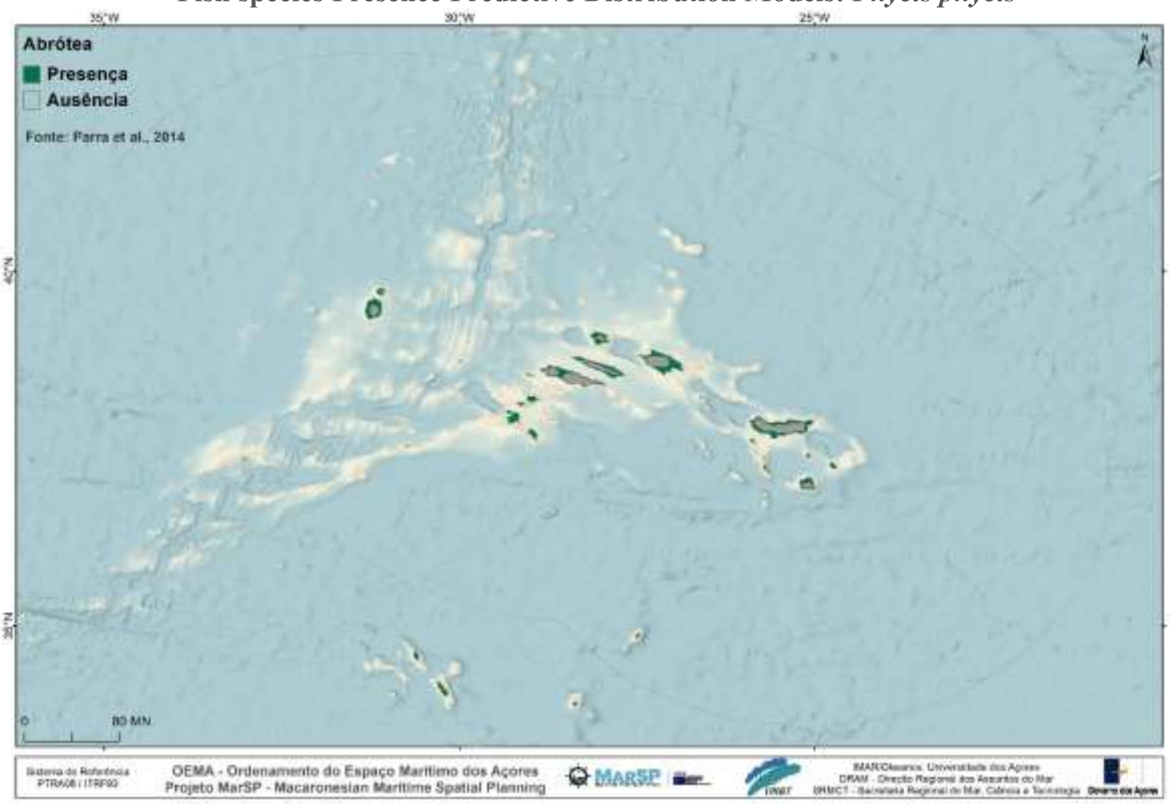
Year: 2017

Keywords: Azores, biota, distribution, demersal fish, economy, forkbeard, modelling, ocean, *Phycis phycis*

Summary: This layer provides geographic information related to a predictive distribution modelling for the demersal fish species *Phycis phycis* (Forkbeard) in the Azorean sea.

The limit value that identifies presence/absence on this specie is **0.137**.

Fish species Presence Predictive Distribution Models: *Phycis phycis*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
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CONTACT'S POSITION Researcher
CONTACT'S ROLE Principal Investigator
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
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* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
X ORIGIN -20037700
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M TOLERANCE 0.001
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3.7.1.2. Presence of *Beryx splendens* / Splendid alfonsino

Raster Dataset: 339.5m (5.76MB)

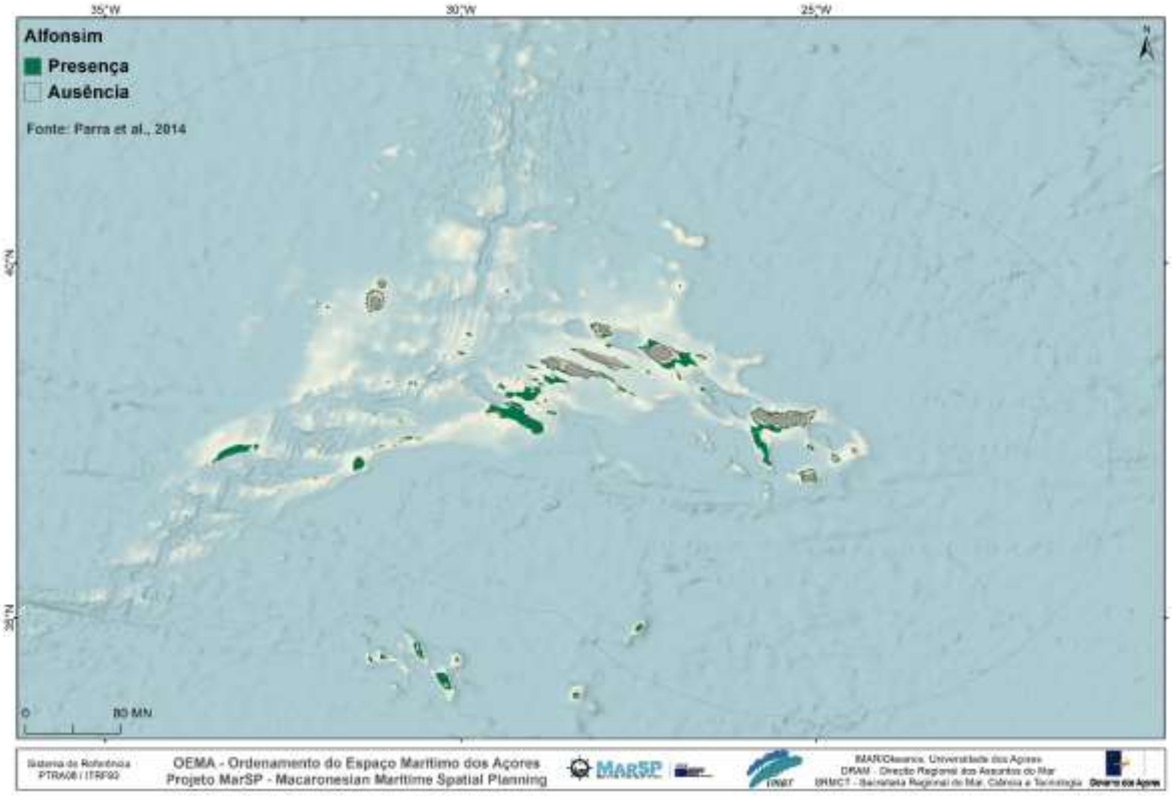
Year: 2017

Keywords: Azores, *Beryx splendens*, biota, distribution, demersal fish, economy, modelling, ocean, Splendid alfonsino

Summary: This layer provides geographic information related to a predictive distribution modelling for the demersal fish species *Beryx splendens* (Splendid alfonsino) in the Azorean sea.

The limit value that identifies presence/absence on this specie is **0.140**.

Fish species Presence Predictive Distribution Models: *Beryx splendens*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
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Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001

M TOLERANCE 0.001 High precision true

WELL-KNOWN TEXT

PROJCS["Mercator_1SP",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["false_easting",0.0],PARAMETER["false_northing",0.0],PARAMETER["central_meridian",0.0],PARAMETER["standard_parallel_1",0.0],UNIT["Meter",1.0]]

3.7.1.3. Presence of *Pontinus kuhlii* / Offshore rockfish

Raster Dataset: 339.5m (5.76MB)

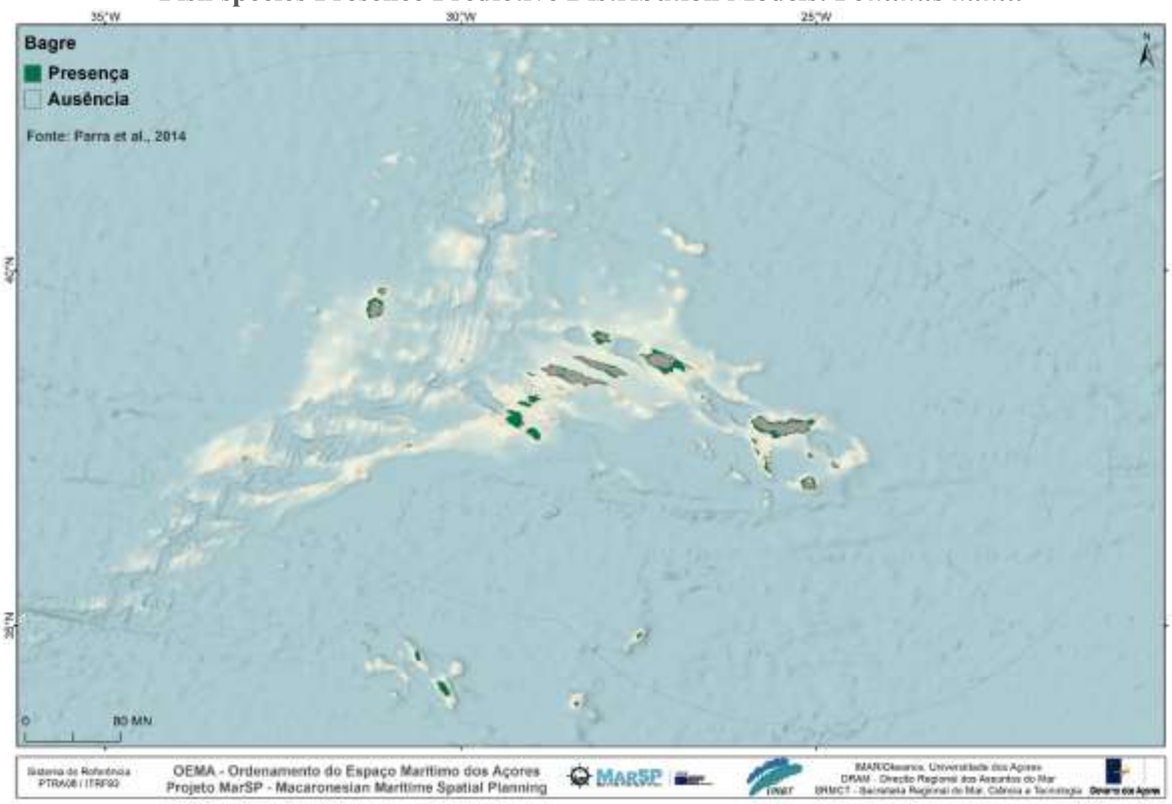
Year: 2017

Keywords: Azores, biota, distribution, demersal fish, economy, modelling, ocean, Offshore rockfish, *Pontinus kuhlii*

Summary: This layer provides geographic information related to a predictive distribution modelling for the demersal fish species *Pontinus kuhlii* (Offshore rockfish) in the Azorean sea.

The limit value that identifies presence/absence on this specie is **0.121**.

Fish species Presence Predictive Distribution Models: *Pontinus kuhlii*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.004142 East -19.997928

North 43.999767 South 32.999484

Citation Contacts:
INDIVIDUAL'S NAME Hugo Parra
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Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
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3.7.1.4. Presence of *Helicolenus dactylopterus* / Blackbelly rosefish

Raster Dataset: 339.5m (5.76MB)

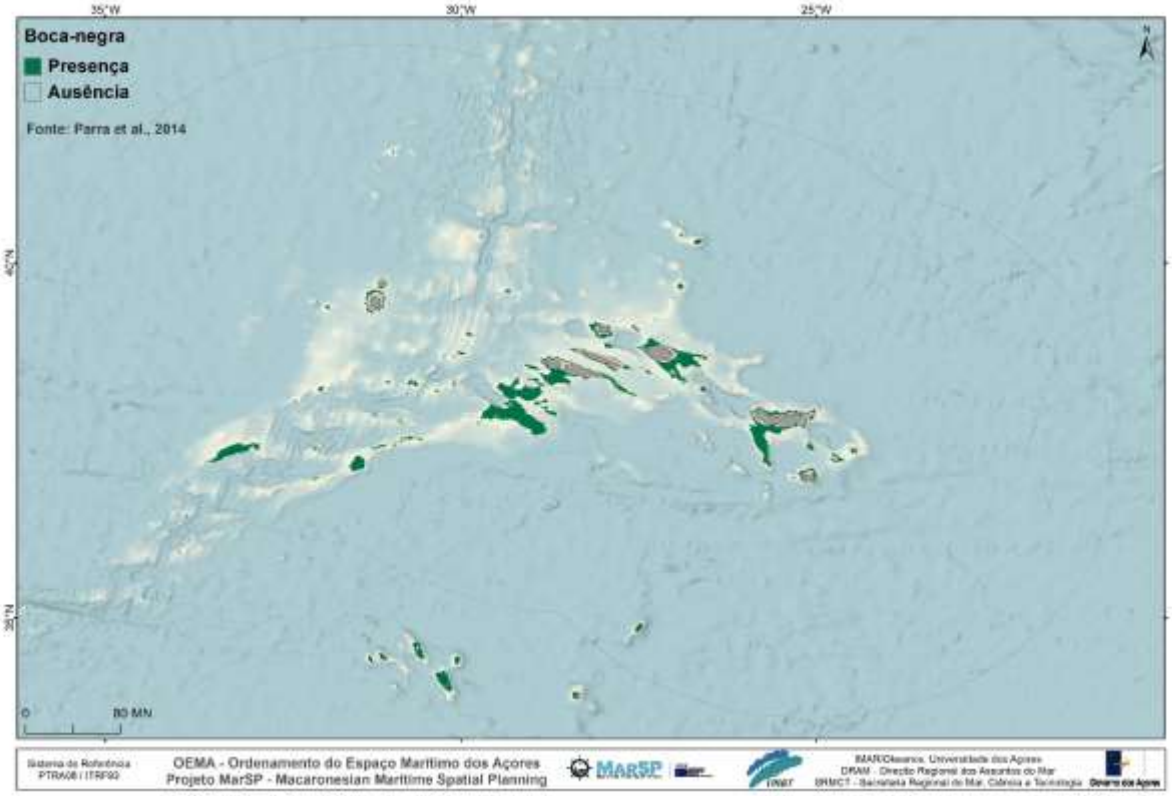
Year: 2017

Keywords: Azores, biota, Blackbelly rosefish, distribution, demersal fish, economy, *Helicolenus dactylopterus*, modelling, ocean

Summary: This layer provides geographic information related to a predictive distribution modelling for the demersal fish species *Helicolenus dactylopterus* (Blackbelly rosefish) in the Azorean sea

The limit value that identifies presence/absence on this specie is **0.451**.

Fish species Presence Predictive Distribution Models: *Helicolenus dactylopterus*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
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Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
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Z ORIGIN -100000
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M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001

M TOLERANCE 0.001 High precision true
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3.7.1.5. Presence of *Polyprion americanus* / Wreckfish

Raster Dataset: 339.5m (5.76MB)

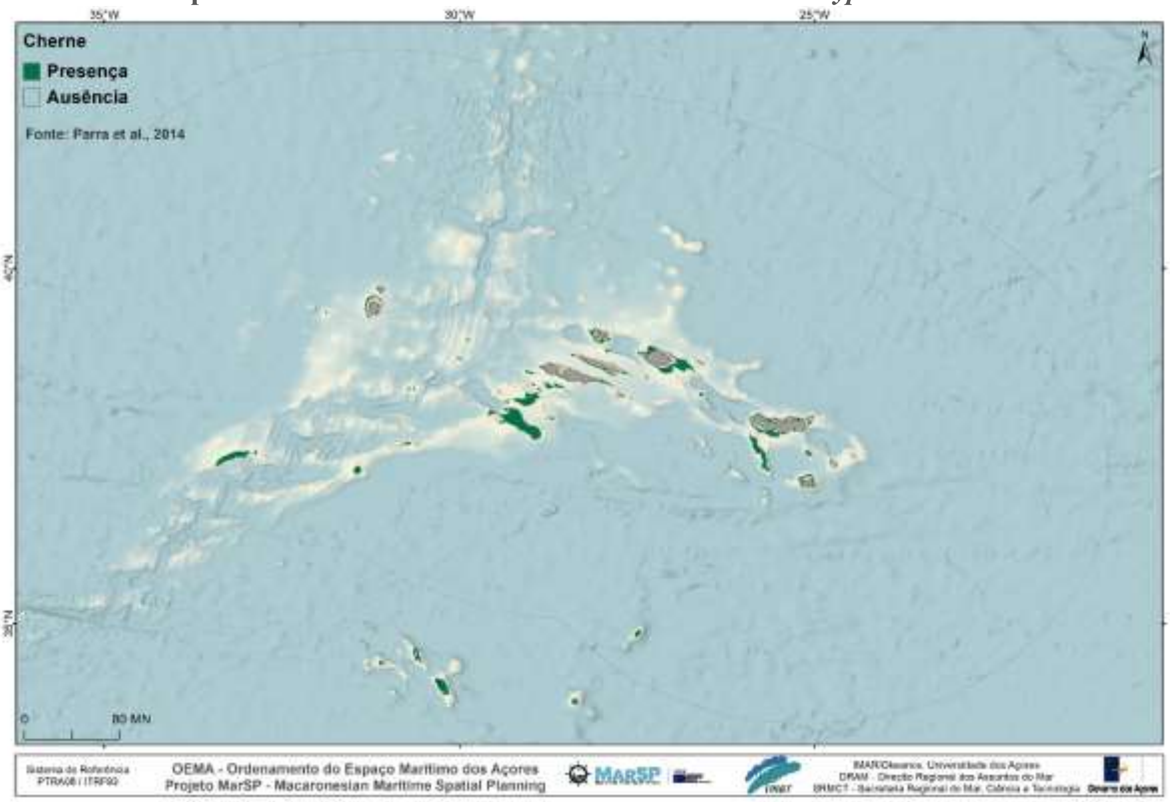
Year: 2017

Keywords: Azores, biota, distribution, demersal fish, economy, modelling, ocean, *Polyprion americanus*, Wreckfish

Summary: This layer provides geographic information related to a predictive distribution modelling for the demersal fish species *Polyprion americanus* (Wreckfish) in the Azorean sea.

The limit value that identifies presence/absence on this specie is **0.037**.

Fish species Presence Predictive Distribution Models: *Polyprion americanus*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.004142 East -19.997928

North 43.999767 South 32.999484

Citation Contacts:

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Spatial Reference:

* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
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M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true

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3.7.1.6. Presence of *Pagellus bogaraveo* / Red sea bream

Raster Dataset: 339.5m (5.76MB)

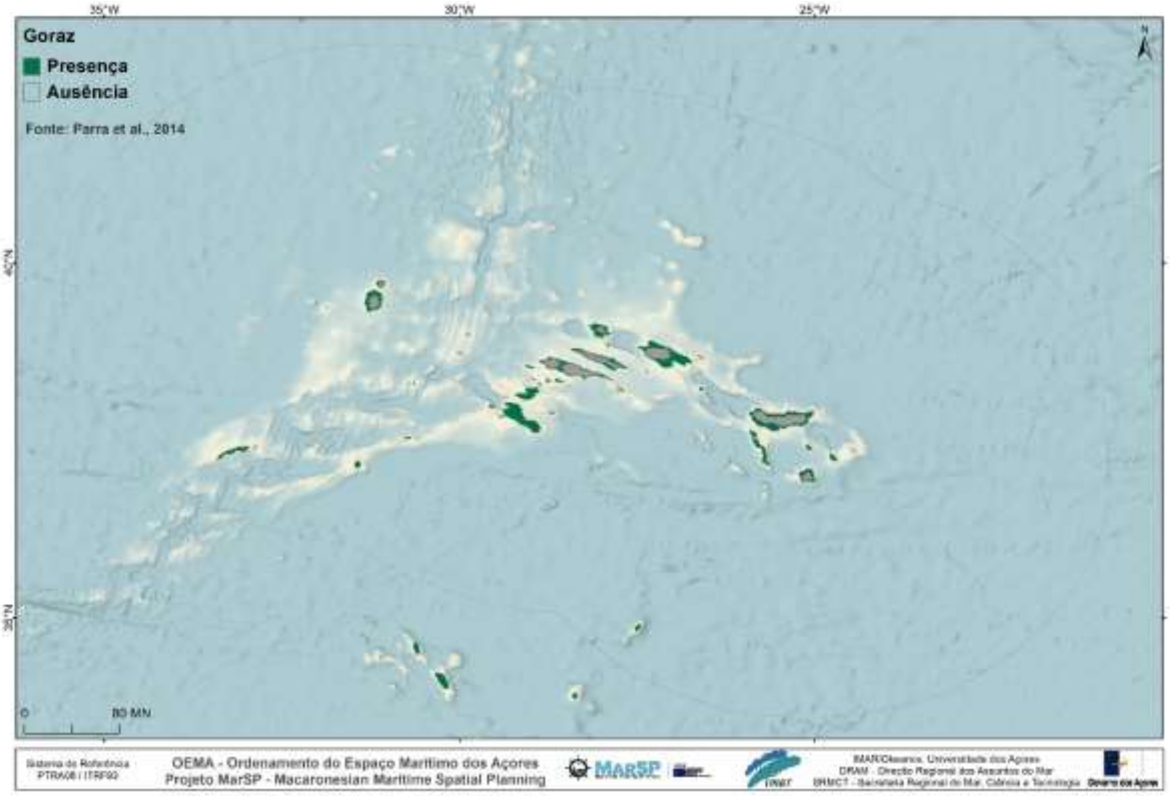
Year: 2017

Keywords: Azores, biota, distribution, demersal fish, economy, modelling, ocean, *Pagellus bogaraveo*, Red sea bream

Summary: This layer provides geographic information related to a predictive distribution modelling for the demersal fish species *Pagellus bogaraveo* (Red sea bream) in the Azorean sea.

The limit value that identifies presence/absence on this specie is **0.466**.

Fish species Presence Predictive Distribution Models: *Pagellus bogaraveo*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
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Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300

XY SCALE 149134210.44795552
Z ORIGIN -100000
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M TOLERANCE 0.001 High precision true

WELL-KNOWN TEXT

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3.7.1.7. Presence of *Beryx decadactylus* / Imperador

Raster Dataset: 339.5m (5.76MB)

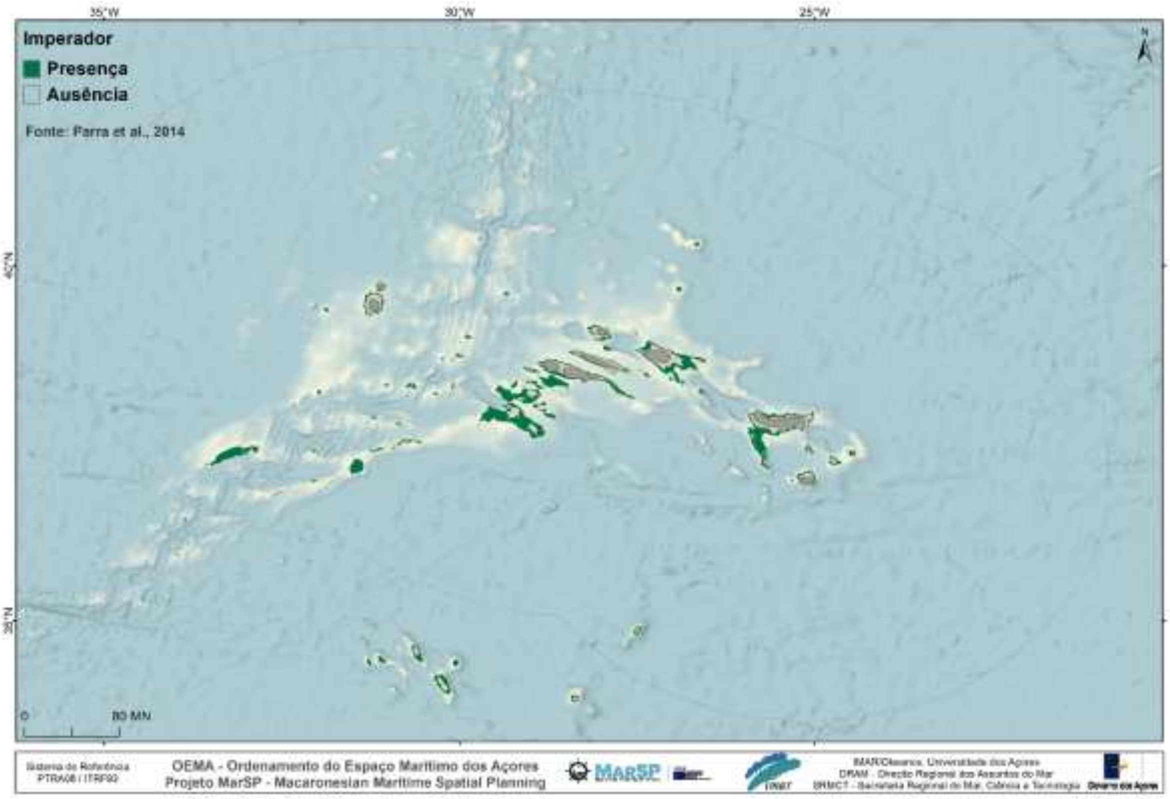
Year: 2017

Keywords: Azores, *Beryx decadactylus*, biota, distribution, demersal fish, economy, imperador, modelling, ocean

Summary: This layer provides geographic information related to a predictive distribution modelling for the demersal fish species *Beryx decadactylus* (Imperador) in the Azorean sea.

The limit value that identifies presence/absence on this specie is **0.139**.

Fish species Presence Predictive Distribution Models: *Beryx decadactylus*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.004142 East -19.997928

North 43.999767 South 32.999484

Citation Contacts:
INDIVIDUAL'S NAME Hugo Parra
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CONTACT'S ROLE Principal Investigator
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
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M SCALE 10000
XY TOLERANCE 0.001
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High precision true
WELL-KNOWN TEXT
PROJCS["Mercator_1SP",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["false_easting",0.0],PARAMETER["false_northing",0.0],PARAMETER["central_meridian",0.0],PARAMETER["standard_parallel_1",0.0],UNIT["Meter",1.0]]

3.7.1.8. Presence of *Pagrus pagrus* / Red porgy

Raster Dataset: 339.5m (5.76MB)

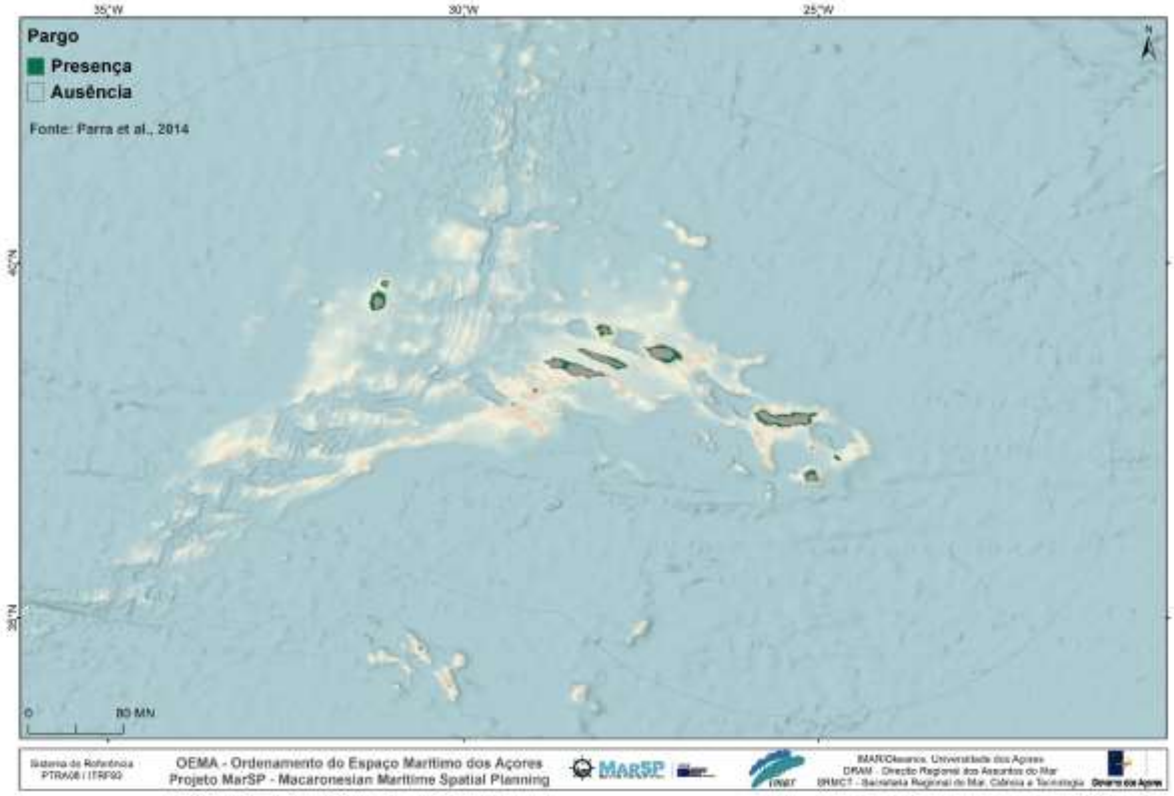
Year: 2017

Keywords: Azores, biota, distribution, demersal fish, economy, modelling, ocean, Pagrus pagrus, Red porgy

Summary: This layer provides geographic information related to a predictive distribution modelling for the demersal fish species Pagrus pagrus (Red porgy) in the Azorean sea.

The limit value that identifies presence/absence on this specie is **0.047**.

Fish species Presence Predictive Distribution Models: ***Pagrus pagrus***



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
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E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300

XY SCALE 149134210.44795552
Z ORIGIN -100000
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M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001

M TOLERANCE 0.001 High precision true

WELL-KNOWN TEXT

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3.7.2. Fish Species Predictive Occurrence Modelling

Raster Dataset Series (6 Models): 279.51m (92.13 MB)

On this raster, models were constructed based on fish occurrence and abundance data gathered from 13 years of bottom longline surveys (470 sets between 1996 and 2011, with the exception of 1998 and 2006, on the research vessel "Arquipélago"), combined with fine scale derived seafloor variables (water column depth, sediment type, bottom slope and aspect, converted into eastness and northness). (Extracted from "Spatial Prediction of demersal fish species presence and abundance in the Azores", Hugo Parra et al., 2017).

In this dataset, there are information about the predicted spatial distributions of the relative abundance of the 6 fish species:

- *Phycis phycis* / Forkbeard;
- *Beryx splendens* / Splendid alfonsino;
- *Pontinus kuhlii* / Offshore rockfish;
- *Helicolenus dactylopterus* / Blackbelly rosefish;
- *Pagellus bogaraveo* / Red sea bream;
- *Beryx decadactylus* / Imperador.

3.7.2.1. Occurrence of *Phycis phycis* / Forkbeard

Raster Dataset: 279.51m (92.13 MB)

Year: 2017

Keywords: Azores, biota, distribution, demersal fish, economy, forkbeard, modelling, ocean, *Phycis phycis*

Summary: This layer provides geographic information related to the predicted spatial distributions of the relative abundance for the demersal fish species *Phycis phycis* (Forkbeard) in the Azorean sea.

Fish species Predictive Occurrence Models: *Phycis phycis*

Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
INDIVIDUAL'S NAME Hugo Parra
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CONTACT'S ROLE Principal Investigator
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
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XY TOLERANCE 0.001
Z TOLERANCE 0.001
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High precision	true
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3.7.2.2. Occurrence of *Beryx splendens* / Splendid alfonsino

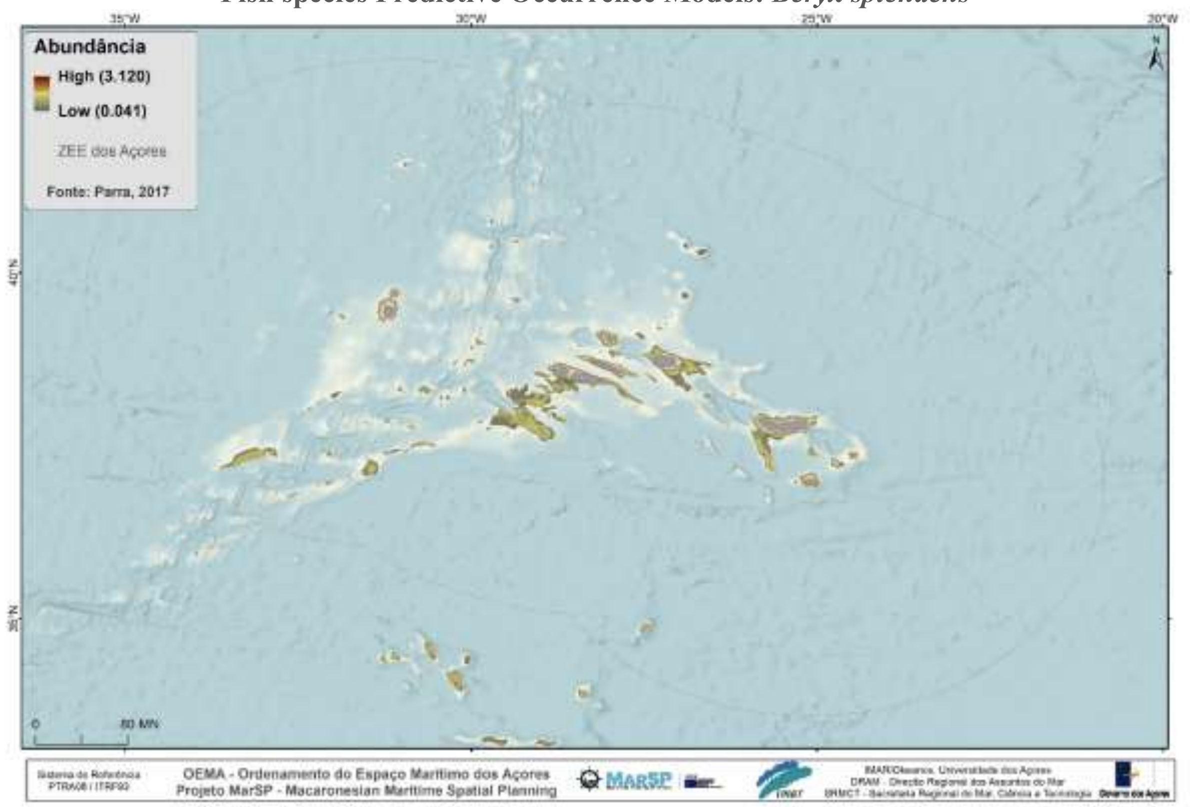
Raster Dataset: 279.51m (92.13 MB)

Year: 2017

Keywords: Azores, *Beryx splendens*, biota, distribution, demersal fish, economy, modelling, ocean, Splendid alfonsino

Summary: This layer provides geographic information related to the predicted spatial distributions of the relative abundance for the demersal fish species *Beryx splendens* (Splendid alfonsino) in the Azorean sea.

Fish species Predictive Occurrence Models: *Beryx splendens*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

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West	-36.004142	East	-19.997928
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Citation Contacts:
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CONTACT'S ROLE Principal Investigator
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
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M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
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3.7.2.3. Occurrence of *Pontinus kuhlii* / Offshore rockfish

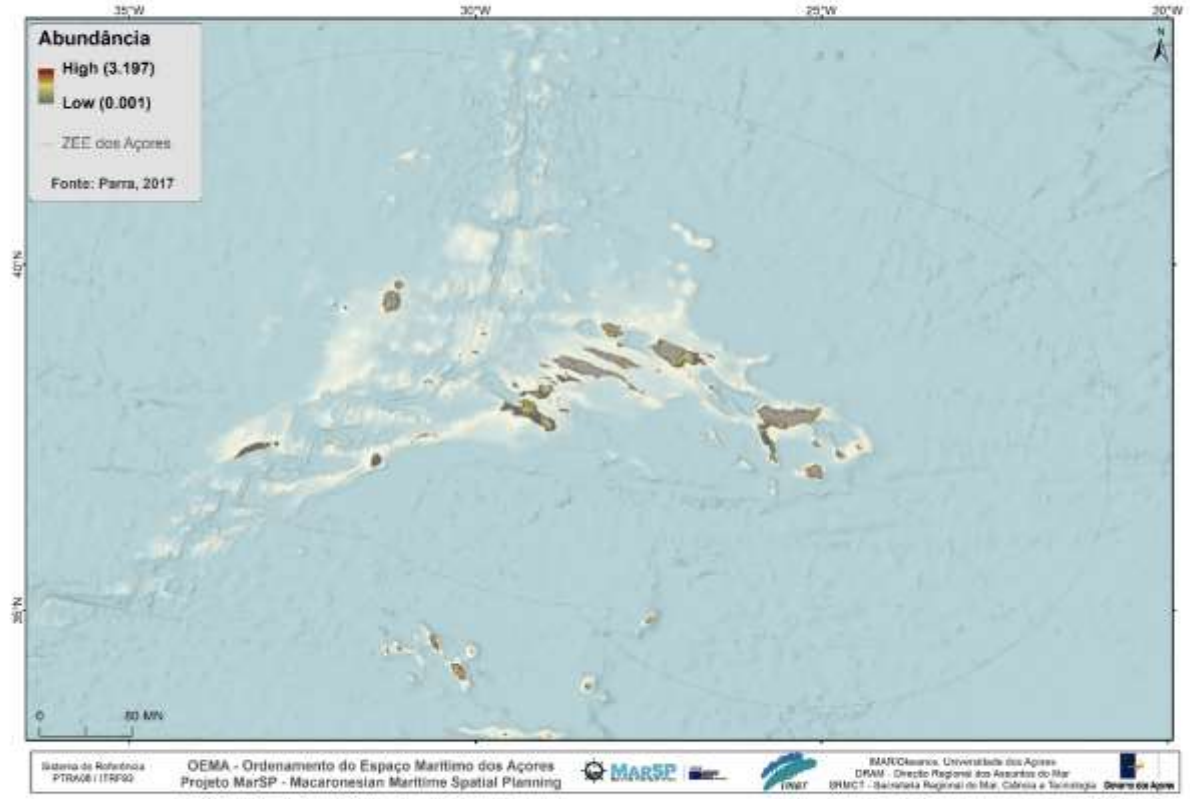
Raster Dataset: 279.51m (92.13 MB)

Year: 2017

Keywords: Azores, biota, distribution, demersal fish, economy, modelling, ocean, Offshore rockfish, *Pontinus kuhlii*

Summary: This layer provides geographic information related to the predicted spatial distributions of the relative abundance for the demersal fish species *Pontinus kuhlii* (Offshore rockfish) in the Azorean sea.

Fish species Predictive Occurrence Models: *Pontinus kuhlii*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

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Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
INDIVIDUAL'S NAME Hugo Parra
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
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Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001

M TOLERANCE 0.001 High precision true

WELL-KNOWN TEXT

PROJCS["Mercator_1SP",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["false_easting",0.0],PARAMETER["false_northing",0.0],PARAMETER["central_meridian",0.0],PARAMETER["standard_parallel_1",0.0],UNIT["Meter",1.0]]

3.7.2.4. Occurrence of *Helicolenus dactylopterus* / Blackbelly rosefish

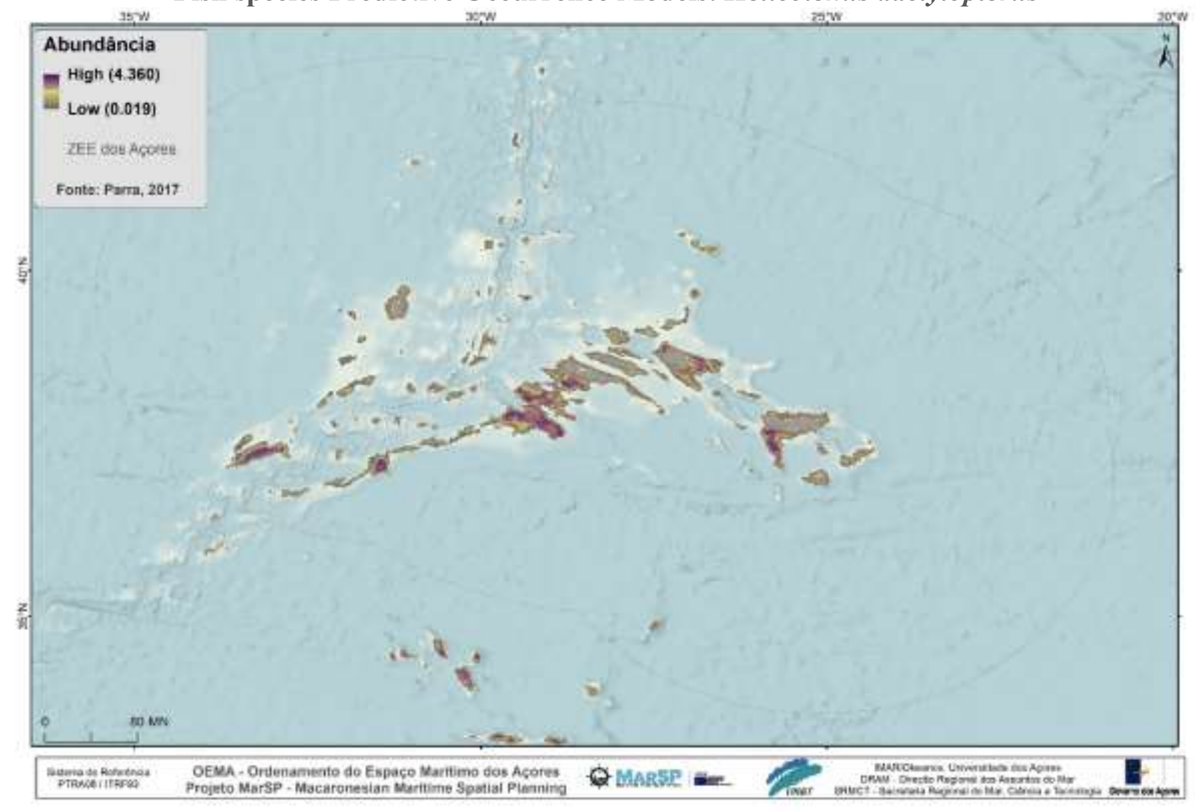
Raster Dataset: 279.51m (92.13 MB)

Year: 2017

Keywords: Azores, biota, Blackbelly rosefish, distribution, demersal fish, economy, *Helicolenus dactylopterus*, modelling, ocean

Summary: This layer provides geographic information related to the predicted spatial distributions of the relative abundance for the demersal fish species *Helicolenus dactylopterus* (Blackbelly rosefish) in the Azorean sea

Fish species Predictive Occurrence Models: *Helicolenus dactylopterus*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
INDIVIDUAL'S NAME Hugo Parra
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Researcher
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS parra.hugo@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
PROJCS["Mercator_1SP",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["false_easting",0.0],PARAMETER["false_northing",0.0],PARAMETER["central_meridian",0.0],PARAMETER["standard_parallel_1",0.0],UNIT["Meter",1.0]]

3.7.2.5. Occurrence of *Pagellus bogaraveo* / Red sea bream

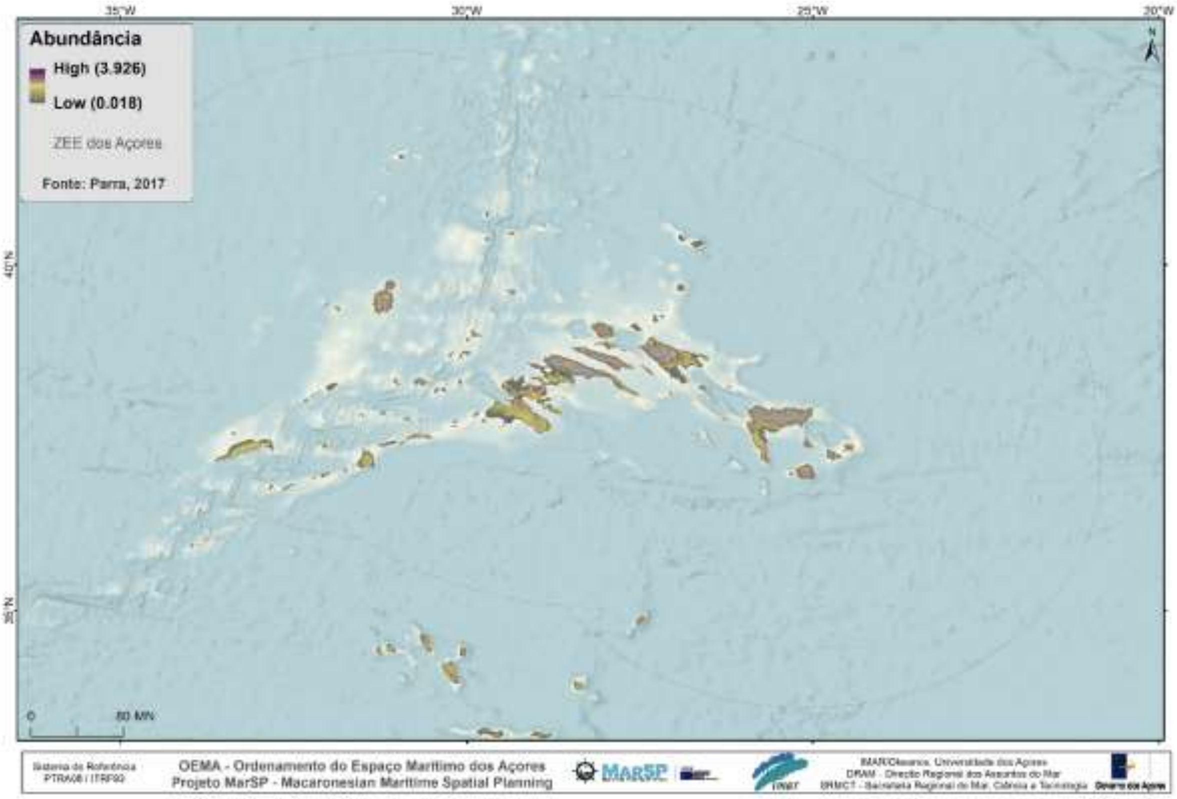
Raster Dataset: 279.51m (92.13 MB)

Year: 2017

Keywords: Azores, biota, distribution, demersal fish, economy, modelling, ocean, *Pagellus bogaraveo*, Red sea bream

Summary: This layer provides geographic information related to the predicted spatial distributions of the relative abundance for the demersal fish species *Pagellus bogaraveo* (Red sea bream) in the Azorean sea.

Fish species Predictive Occurrence Models: *Pagellus bogaraveo*



Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
INDIVIDUAL'S NAME Hugo Parra
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Researcher
CONTACT'S ROLE Principal Investigator
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Point of Contact:
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001

M TOLERANCE 0.001 High precision true

WELL-KNOWN TEXT

PROJCS["Mercator_1SP",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["false_easting",0.0],PARAMETER["false_northing",0.0],PARAMETER["central_meridian",0.0],PARAMETER["standard_parallel_1",0.0],UNIT["Meter",1.0]]

3.7.2.6. Occurrence of *Beryx decadactylus* / Imperador

Raster Dataset: 279.51m (92.13 MB)

Year: 2017

Keywords: Azores, *Beryx decadactylus*, biota, distribution, demersal fish, economy, imperador, modelling, ocean

Summary: This layer provides geographic information related to the predicted spatial distributions of the relative abundance for the demersal fish species *Beryx decadactylus* (Imperador) in the Azorean sea.

Fish species Predictive Occurrence Models: *Beryx decadactylus*

Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-36.004142	East	-19.997928
North	43.999767	South	32.999484

Citation Contacts:
INDIVIDUAL'S NAME Hugo Parra
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Researcher
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS parra.hugo@gmail.com

INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Point of Contact:

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION Mercator_1SP
Projected coordinate system
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
WELL-KNOWN TEXT
PROJCS["Mercator_1SP",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["false_easting",0.0],PARAMETER["false_northing",0.0],PARAMETER["central_meridian",0.0],PARAMETER["standard_parallel_1",0.0],UNIT["Meter",1.0]]

3.8. Marine Important seabird areas in the Azores

The spatial structure and distribution at sea of Cory's shearwaters (*Calonectris diomedea borealis*), common terns (*Sterna hirundo*), and roseate terns (*Sterna dougallii*) were analysed in the Azores for various environmental factors: sea surface temperature, chlorophyll a concentration, distance to fronts, wind, distance to island shore or tern colonies, distance to seamounts, seabed slope, and depth.

Data on seabird sightings were collected by observers on board fishing vessels, 2002–2006. Generalized linear modelling (GLM) explained 43 and 11% of the abundance variability for terns (both species pooled) and Cory's shearwaters, respectively.

Variability in seabird abundance was mainly explained by month, wind, distance to shore and/or tern colonies, and distance to seamounts. Variogram modelling indicated that species distribution presented a small-scale spatial structure (i.e. low autocorrelation).

In this dataset, there are information about predicted distribution models of 3 marine important seabird species:

- *Calonectris diomedea borealis* / Cory's shearwater (from May to October) – 6 models
- *Sterna hirundo* / Common tern (from May to October) – 6 models
- *Sterna dougallii* / Roseate tern (from May to August) – 4 models

3.8.1. Predicted distribution of *Calonectris diomedea borealis* / Cory's shearwater

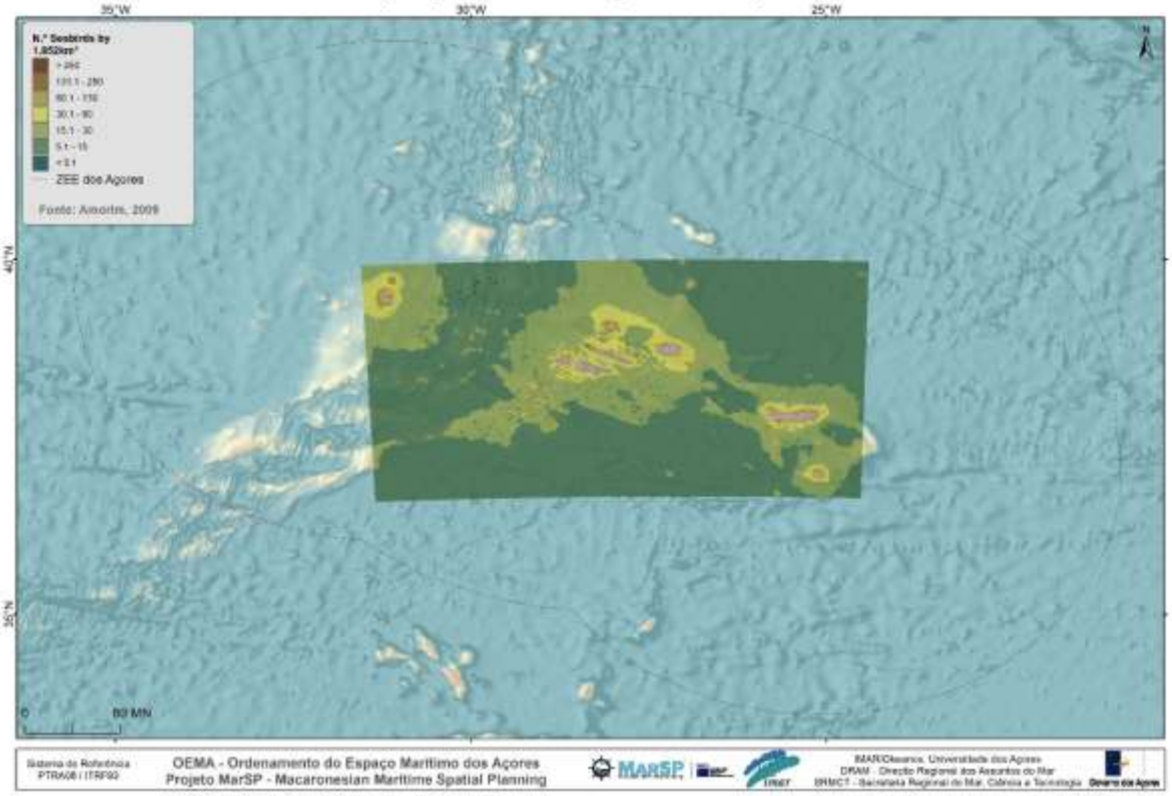
Raster Dataset Series (6 models): 1862m (1,21Mb)

Year: 2009

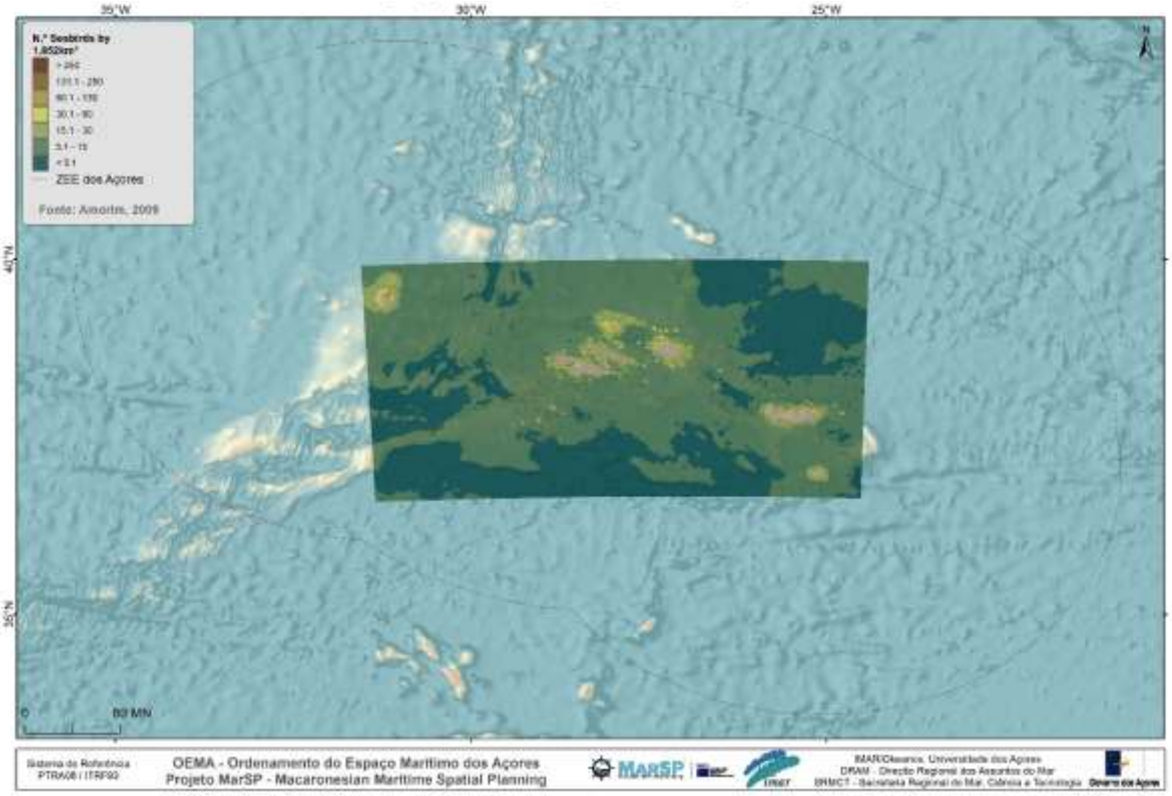
Keywords: Azores, geostatistics, marine IBAs, regression models, seabirds, spatial statistics

Summary: Six maps of predicted distribution of Cory's shearwater (*Calonectris diomedea borealis*) in the Azores (from May to October).

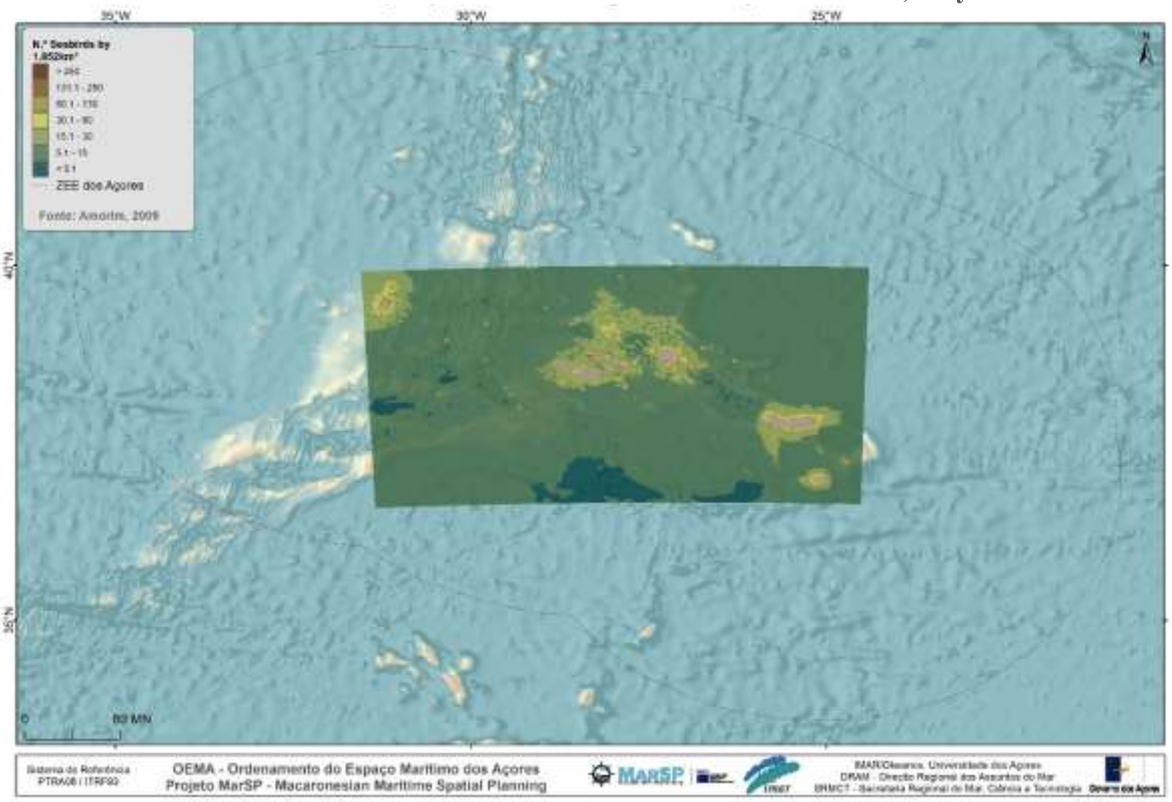
Predictive distribution of *Calonectris diomedea borealis*, May



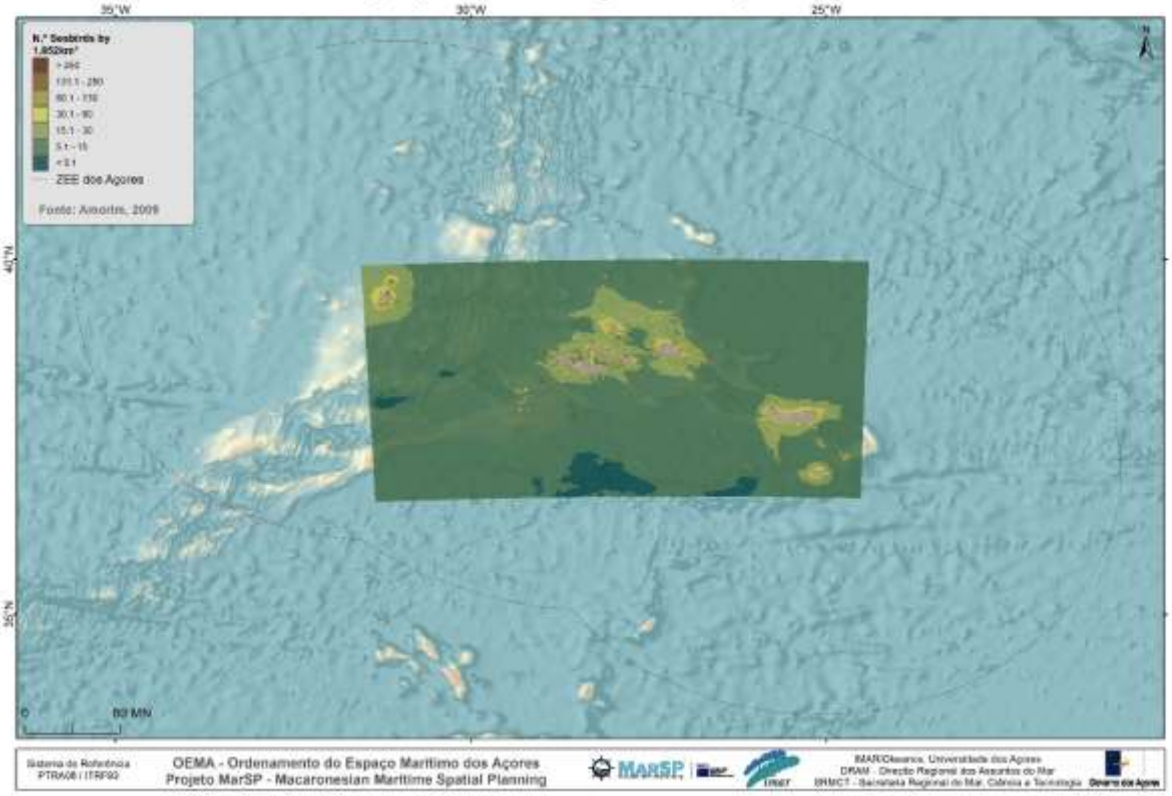
Predictive distribution of *Calonectris diomedea borealis*, June



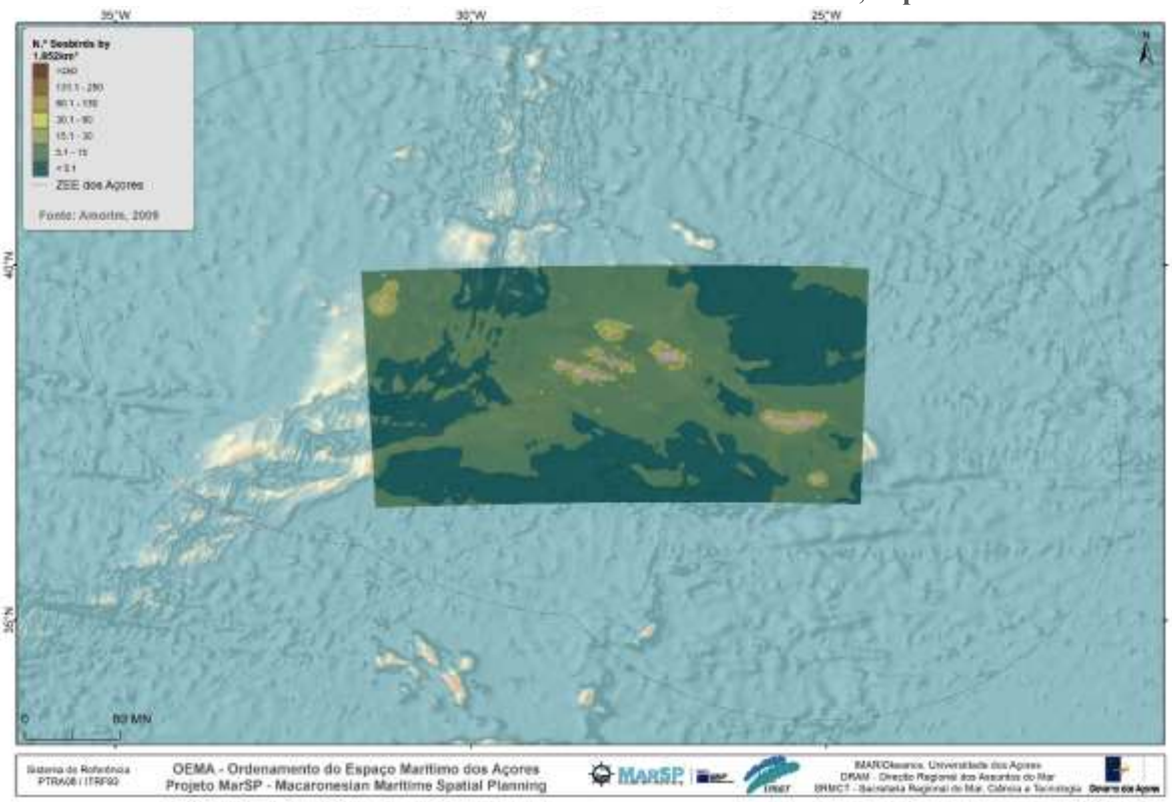
Predictive distribution of *Calonectris diomedea borealis*, July



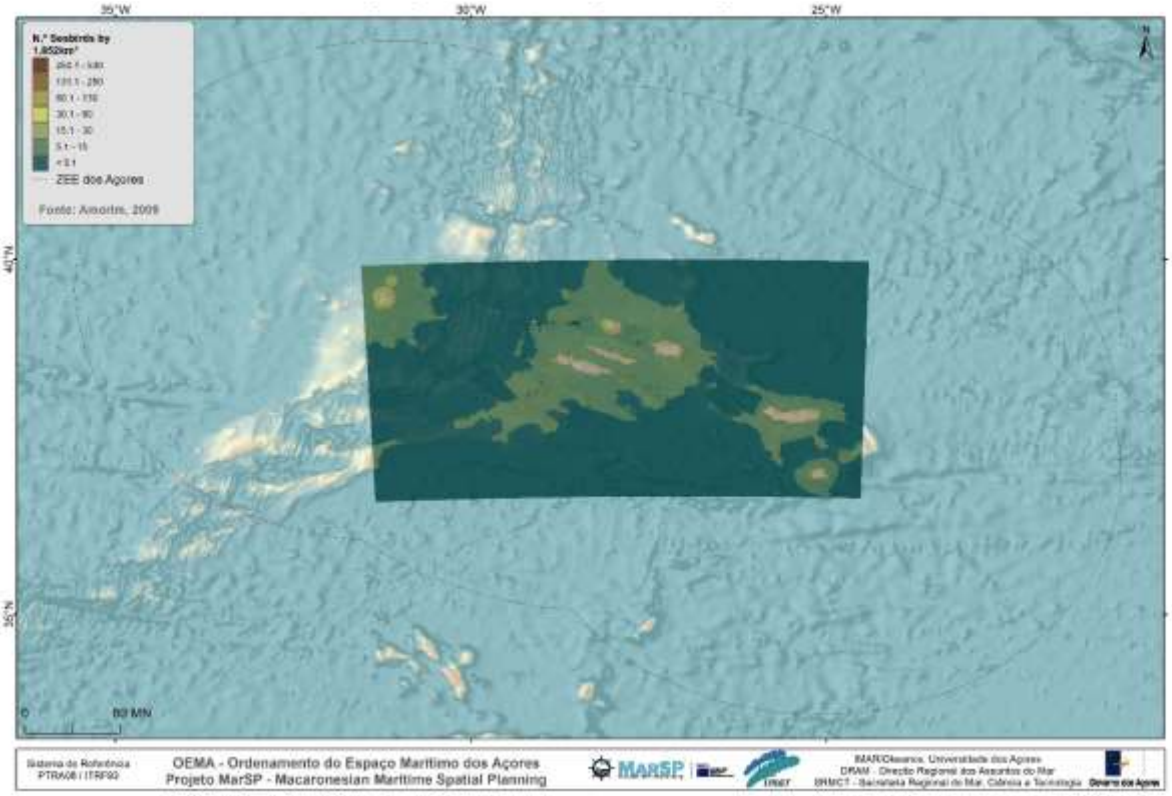
Predictive distribution of *Calonectris diomedea borealis*, August



Predictive distribution of *Calonectris diomedea borealis*, September



Predictive distribution of *Calonectris diomedea borealis*, October



Description: Cory's shearwater predictive distribution maps showed widespread distribution patterns of abundance, despite occurring at a greater intensity around the islands and around some seamounts, which are areas of fishery interest.

Reference: Tobeña, M., Prieto, R., Machete, M., and Silva, M. A. (2016). Modeling the potential distribution and richness of cetaceans in the Azores from fisheries observer program data. Front. Mar. Sci. 3:202. doi: 10.3389/fmars.2016.00202.

Data on seabirds were collected during the Azores Fisheries Observers Programme (POPA; www.popaobserver.org). The programme runs with trained observers on board fishing vessels, recording georeferenced data on fishing activities and other relevant information, such as sightings of associated species of cetaceans, seabirds, and sea turtles (Feio et al., 2005; Machete and Santos, 2007; Morato et al., 2008a). Data on seabird sightings were collected using a snapshot type of methodology, i.e. counting seabirds sighted around the boat (up to 300 m) during six daily fixed periods, separated by 2-h intervals (09:00, 11:00, 13:00, 15:00, 17:00, and 19:00). If no seabirds were observed, a zero count was recorded. Otherwise, seabird sightings were recorded in quantity ranges (shearwaters: 1 –10, 11 –25, 26 –50, 51 –100, 101 –250, 251 –500, 501–1000, and .1000; terns: 1–3, 4 –10, 11 –25, 26–50, 51 –75, 76–100, and .100). These categorical data were converted into continuous variables by assigning the mean value of each class of abundance.

Credits: IMAR/Okeanos. University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-31.547617	East	-24.396077
North	39.997705	South	36.580242

Citation Contacts:
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ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
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E-MAIL ADDRESS amorim.patricia@gmail.com

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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Researcher
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:

* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details

Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
WELL-KNOWN TEXT
PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

3.8.2. Predicted distribution of *Sterna hirundo* / Common tern

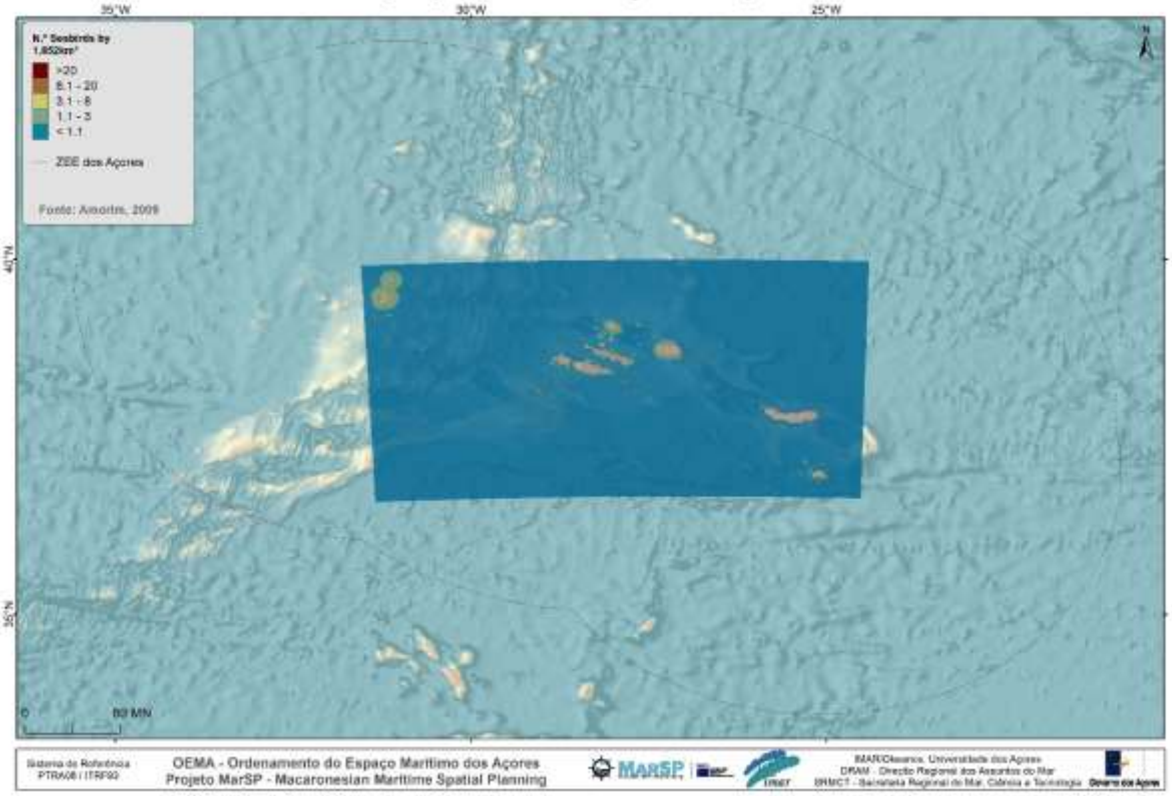
Raster Dataset Series (6 models): 1862m (1,21Mb)

Year: 2009

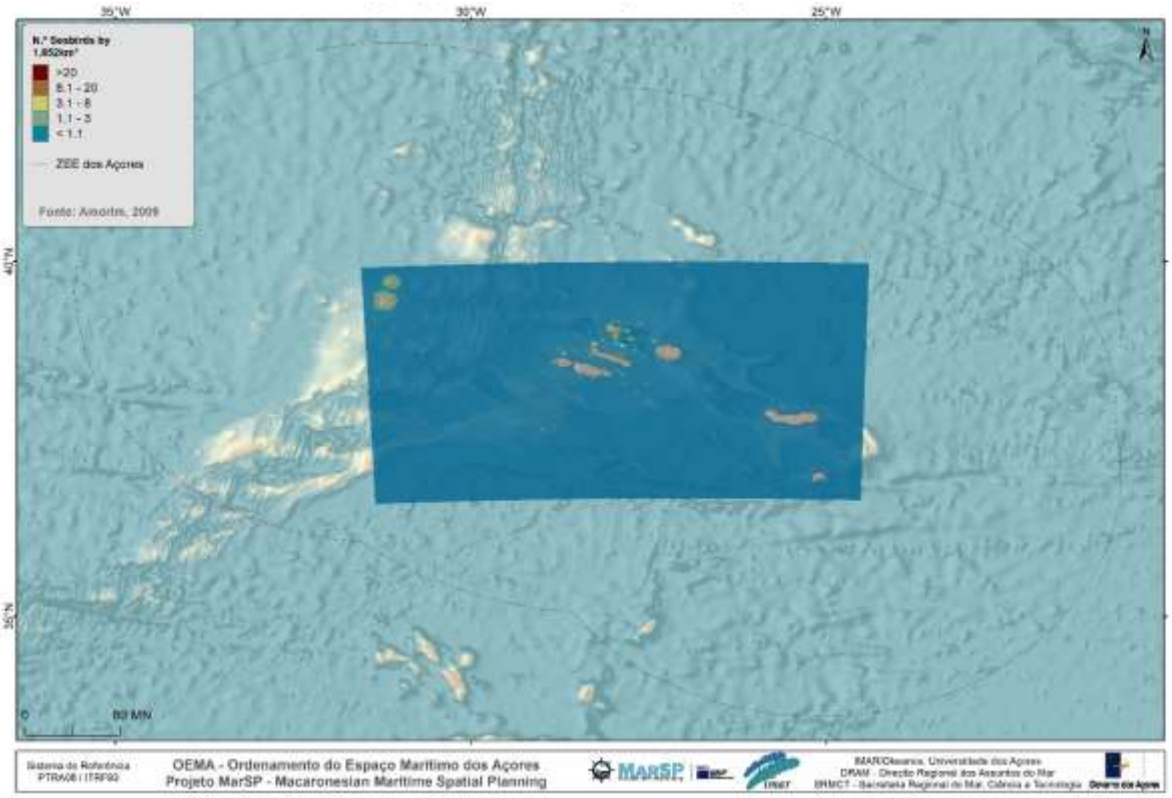
Keywords: Azores, geostatistics, marine IBAs, regression models, seabirds, spatial statistics

Summary: Six maps of predicted distribution of Common tern (*Sterna hirundo*) in the Azores (from May to October).

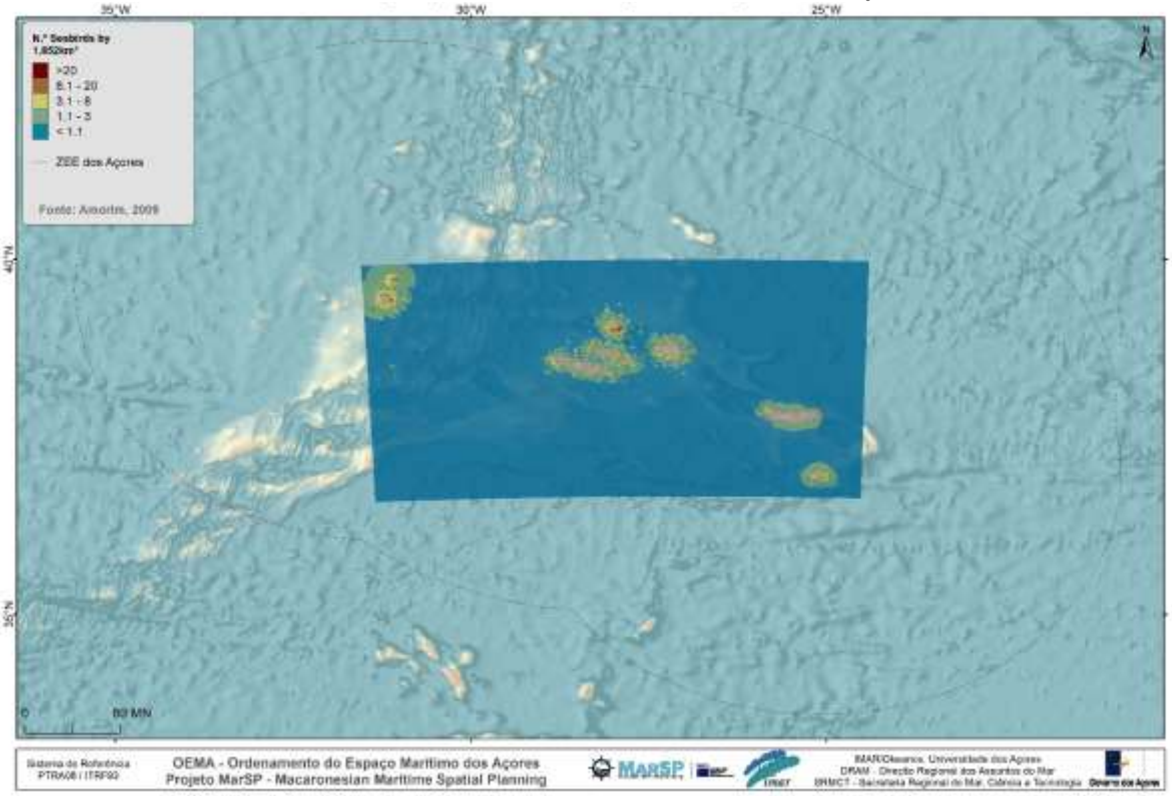
Predictive distribution of *Sterna hirundo*, May



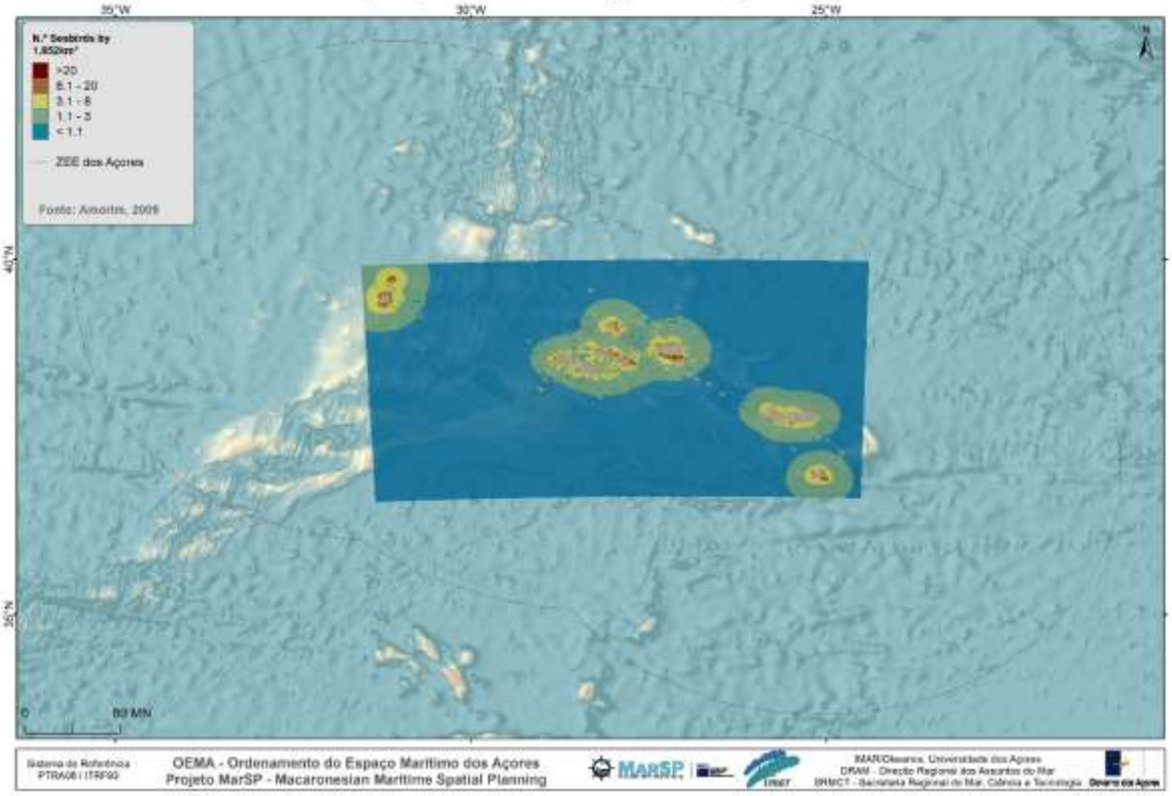
Predictive distribution of *Sterna hirundo*, June



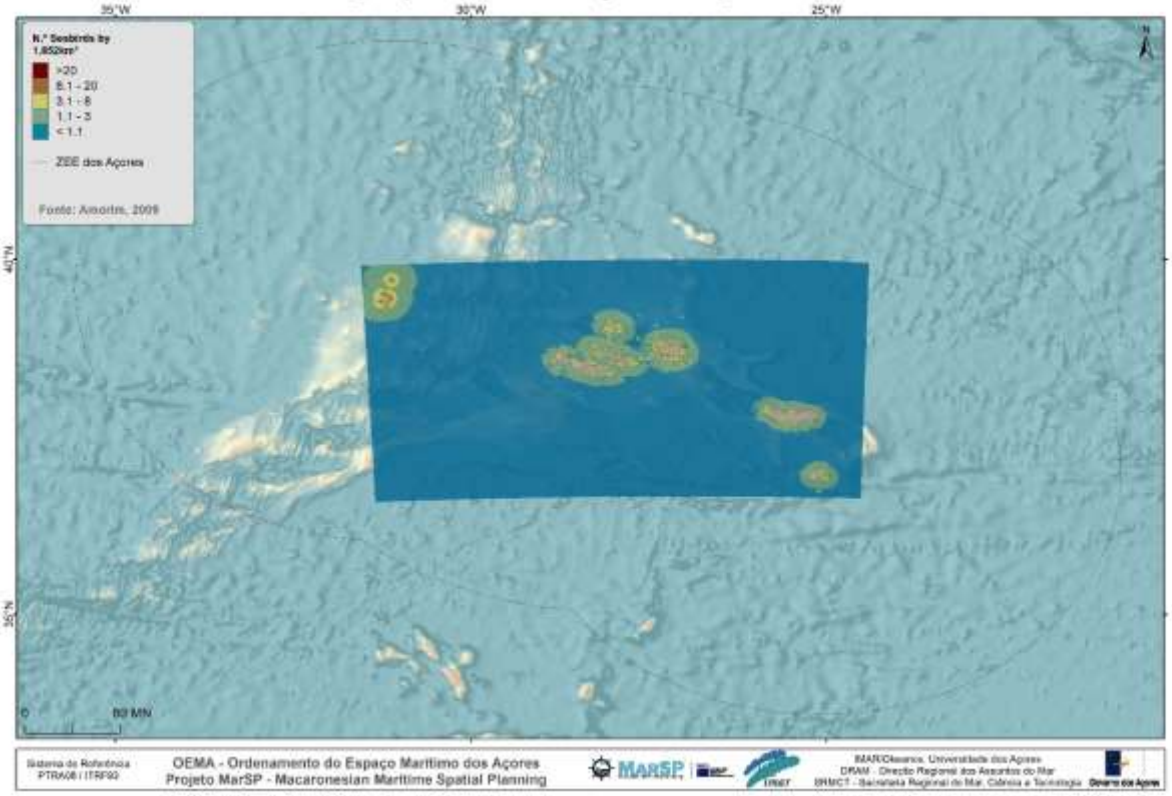
Predictive distribution of *Sterna hirundo*, July



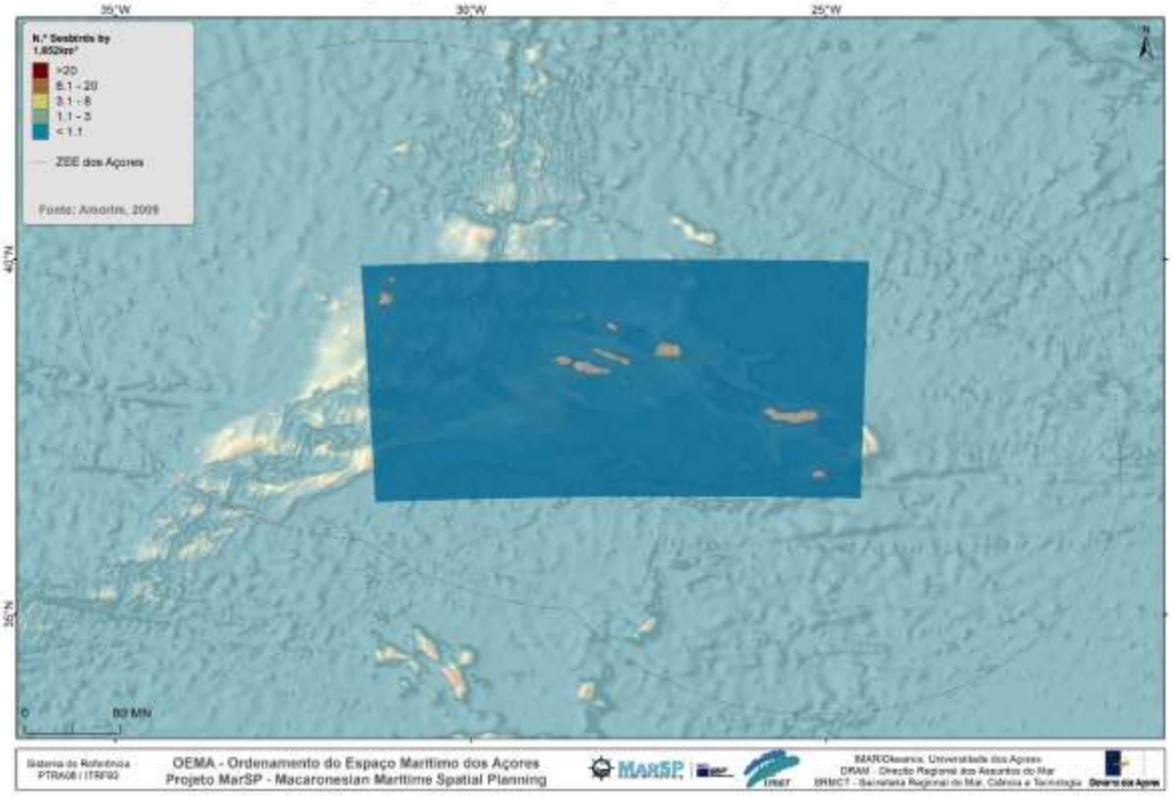
Predictive distribution of *Sterna hirundo*, August



Predictive distribution of *Sterna hirundo*, September



Predictive distribution of *Sterna hirundo*, October



Description: Common tern predictive distribution maps showed widespread distribution patterns of abundance, despite occurring at a greater intensity around the islands and around some seamounts, which are areas of fishery interest.

Data on seabirds were collected during the Azores Fisheries Observers Programme (POPA; www.popaobserver.org). The programme runs with trained observers on board fishing vessels, recording georeferenced data on fishing activities and other relevant information, such as sightings of associated species of cetaceans, seabirds, and sea turtles (Feio et al., 2005; Machete and Santos, 2007; Morato et al., 2008a). Data on seabird sightings were collected using a snapshot type of methodology, i.e. counting seabirds sighted around the boat (up to 300 m) during six daily fixed periods, separated by 2-h intervals (09:00, 11:00, 13:00, 15:00, 17:00, and 19:00). If no seabirds were observed, a zero count was recorded. Otherwise, seabird sightings were recorded in quantity ranges (shearwaters: 1 –10, 11 –25, 26 –50, 51 –100, 101 –250, 251 –500, 501–1000, and .1000; terns: 1–3, 4 –10, 11 –25, 26–50, 51 –75, 76–100, and .100). These categorical data were converted into continuous variables by assigning the mean value of each class of abundance.

Reference: Tobeña, M., Prieto, R., Machete, M., and Silva, M. A. (2016). Modeling the potential distribution and richness of cetaceans in the Azores from fisheries observer program data. Front. Mar. Sci. 3:202. doi: 10.3389/fmars.2016.00202.

Credits: IMAR/Okeanos. University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-31.547617	East	-24.396077
North	39.997705	South	36.580242

Citation Contacts:
INDIVIDUAL'S NAME Patrícia Amorim
ORGANIZATION'S NAME IMAR/Okeanos. Universidade dos Açores
CONTACT'S POSITION Researcher
E-MAIL ADDRESS amorim.patricia@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Researcher
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
WELL-KNOWN TEXT
PROJCS["WGS_1984_UTM_ZONE_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984", SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["GREENWICH",0.0],UNIT["DEGREE",0.0174532925199433]],PROJECTION["TRANSVERSE_MERCATOR"],PARAMETER["FALSE_EASTING",500000.0],PARAMETER["FALSE_NORTHING",0.0],PARAMETER["CENTRAL_MERIDIAN",-

27.0],PARAMETER["SCALE_FACTOR",0.9996],PARAMETER["LATITUDE_OF_ORIGIN",0.0],UNIT["METER",1.0],AUTHORITY["EPSG",32626]]

3.8.3. Predicted distribution of *Sterna dougallii* / Roseate tern

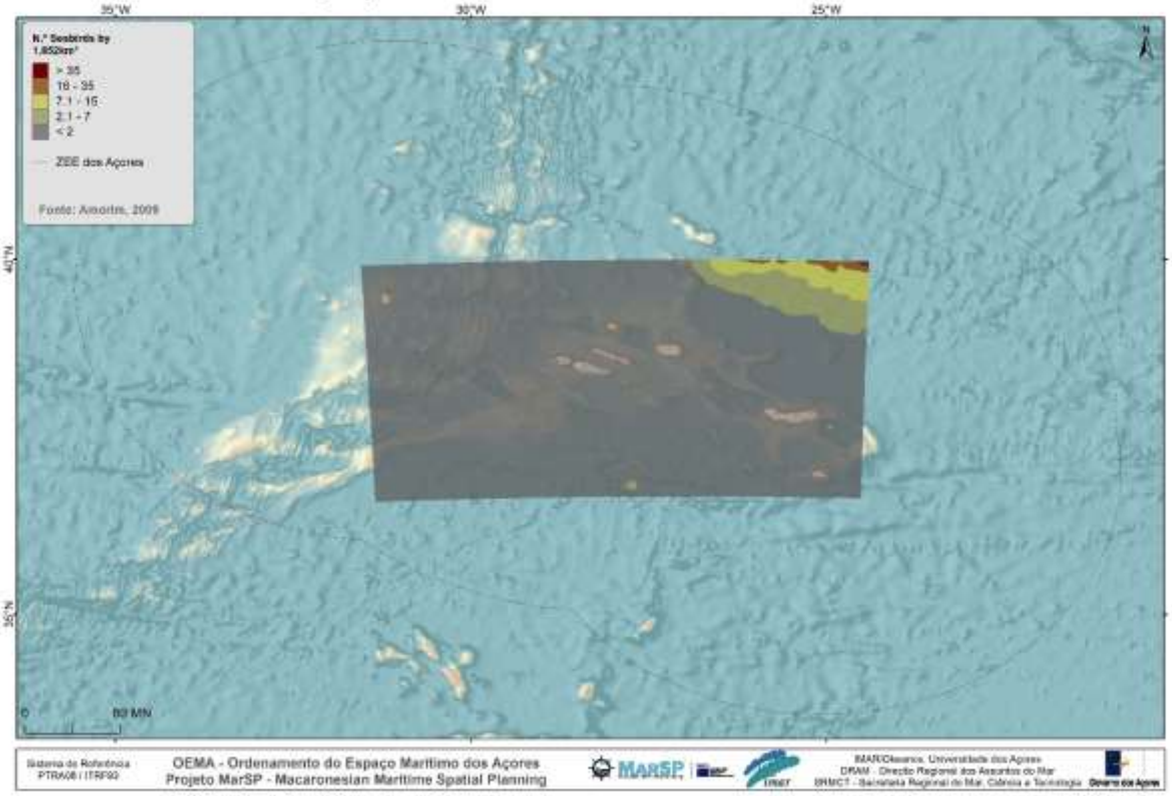
Raster Dataset Series (4 models): 1862m (1,21Mb)

Year: 2009

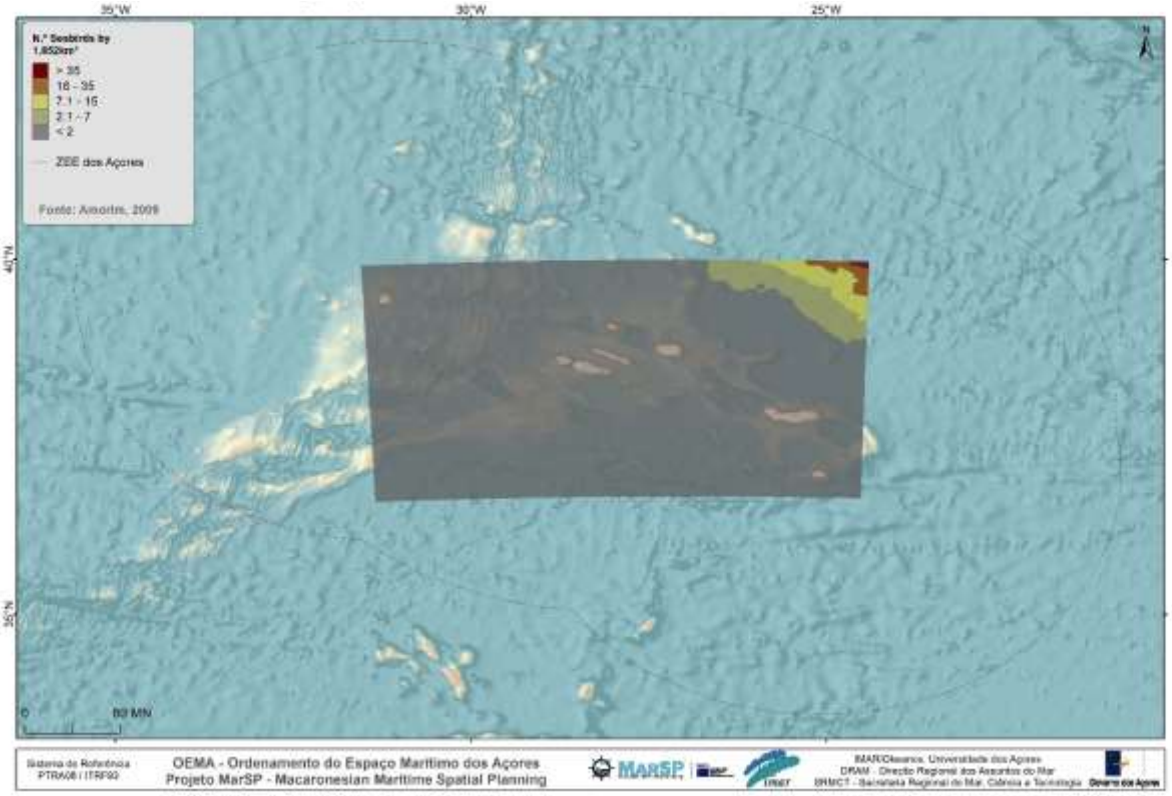
Keywords: Azores, geostatistics, marine IBAs, regression models, seabirds, spatial statistics

Summary: Four maps of predicted distribution of Roseate tern (*Sterna dougallii*) in the Azores (from May to August).

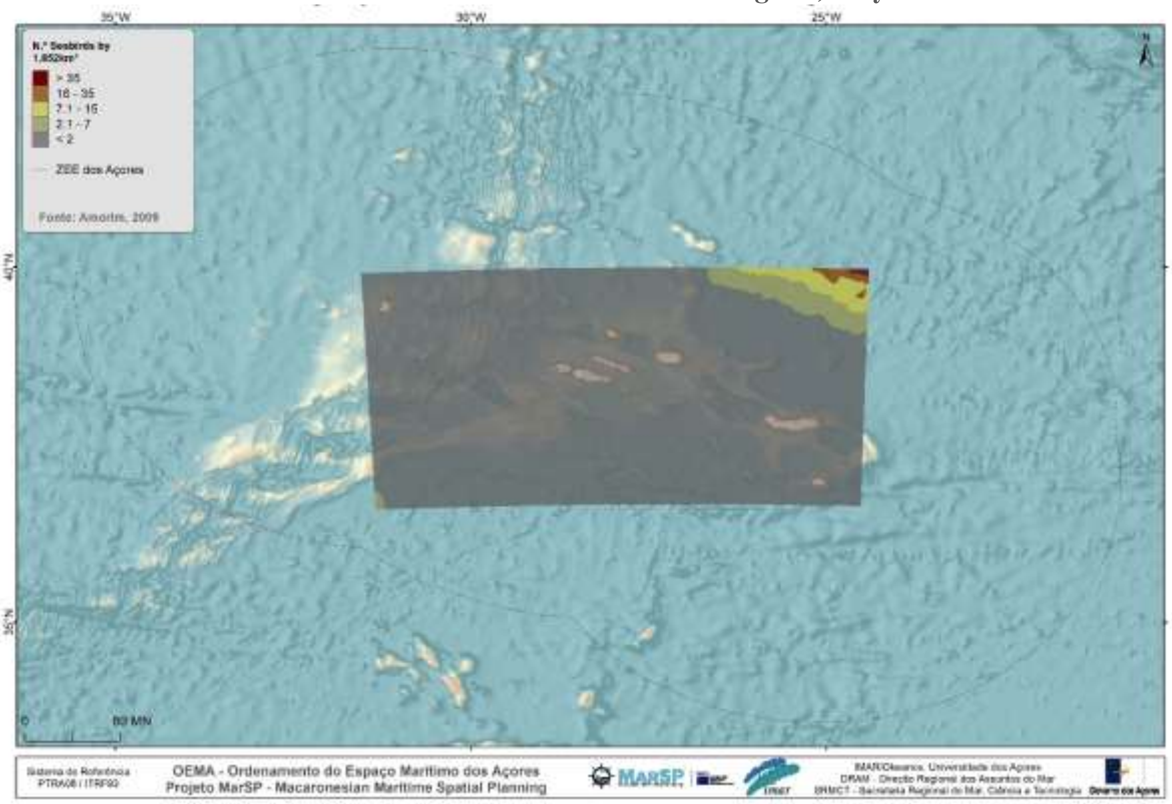
Predictive distribution of *Sterna dougallii*, May



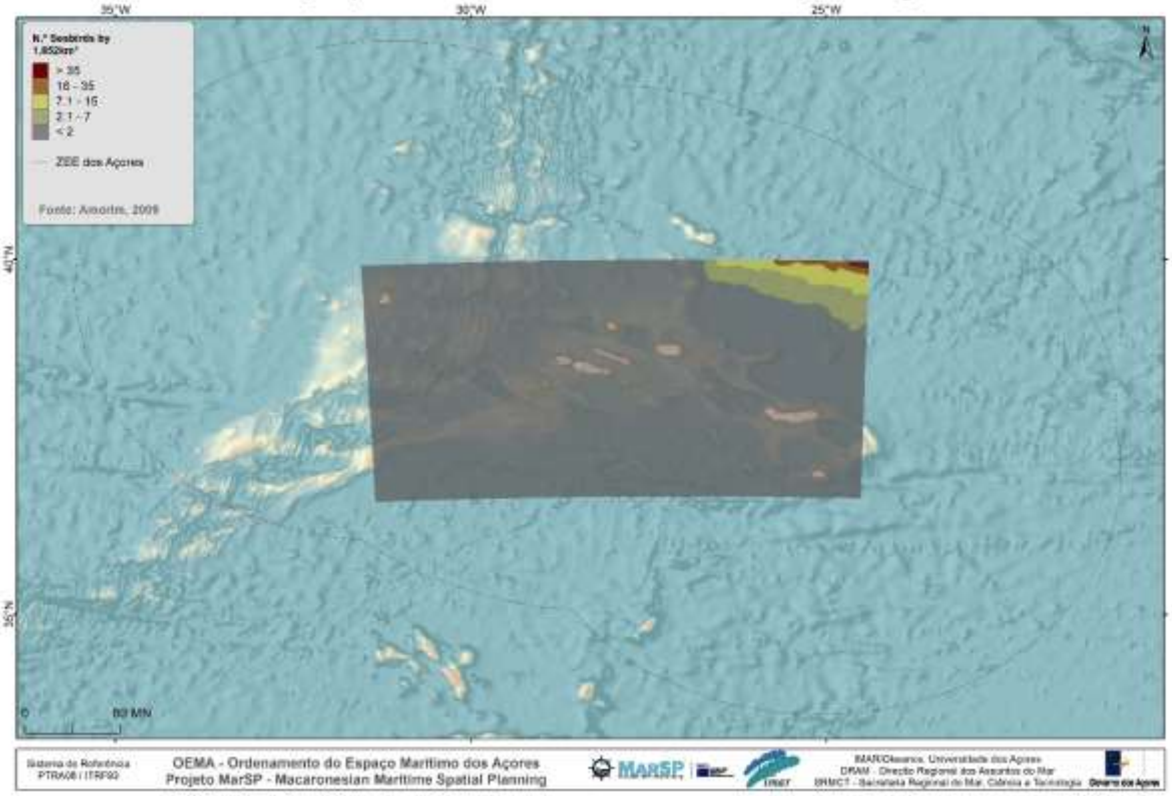
Predictive distribution of *Sterna dougallii*, June



Predictive distribution of *Sterna dougallii*, July



Predictive distribution of *Sterna dougallii*, August



Description: Roseate tern predictive distribution maps showed widespread distribution patterns of abundance, despite occurring at a greater intensity around the islands and around some seamounts, which are areas of fishery interest.

Data on seabirds were collected during the Azores Fisheries Observers Programme (POPA; www.popaobserver.org). The programme runs with trained observers on board fishing vessels, recording georeferenced data on fishing activities and other relevant information, such as sightings of associated species of cetaceans, seabirds, and sea turtles (Feio et al., 2005; Machete and Santos, 2007; Morato et al., 2008a). Data on seabird sightings were collected using a snapshot type of methodology, i.e. counting seabirds sighted around the boat (up to 300 m) during six daily fixed periods, separated by 2-h intervals (09:00, 11:00, 13:00, 15:00, 17:00, and 19:00). If no seabirds were observed, a zero count was recorded. Otherwise, seabird sightings were recorded in quantity ranges (shearwaters: 1 –10, 11 –25, 26 –50, 51 –100, 101 –250, 251 –500, 501–1000, and .1000; terns: 1–3, 4 –10, 11 –25, 26–50, 51 –75, 76–100, and .100). These categorical data were converted into continuous variables by assigning the mean value of each class of abundance.

Reference: Tobeña, M., Prieto, R., Machete, M., and Silva, M. A. (2016). Modeling the potential distribution and richness of cetaceans in the Azores from fisheries observer program data. Front. Mar. Sci. 3:202. doi: 10.3389/fmars.2016.00202.

Credits: IMAR/Okeanos. University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -31.547617 East -24.396077
North 39.997705 South 36.580242

Citation Contacts:
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E-MAIL ADDRESS amorim.patricia@gmail.com

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Researcher
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
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Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
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M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
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Latest well-known identifier 32626
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3.9. Vulnerable Marine Ecosystems (VME)

In international fisheries management, scientific advice on the presence of “vulnerable marine ecosystems” (VMEs) per United Nations resolutions, has generally used qualitative assessments based on expert judgment of the occurrence of indicator taxa such as cold-water corals and sponges. Use of expert judgment alone can be criticized for inconsistency and sometimes a lack of transparency; therefore, development of robust and repeatable numeric methods to detect the presence of VMEs would be advantageous. Here, we present a multi-criteria assessment (MCA) method to evaluate how likely a given area of seafloor represents a VME. The MCA is a taxa-dependent spatial method that accounts for both the quantity and data quality available. This was applied to a database of records of VMEs built, held and compiled by the International Council for the Exploration of the Sea (ICES).

3.9.1. VME Score

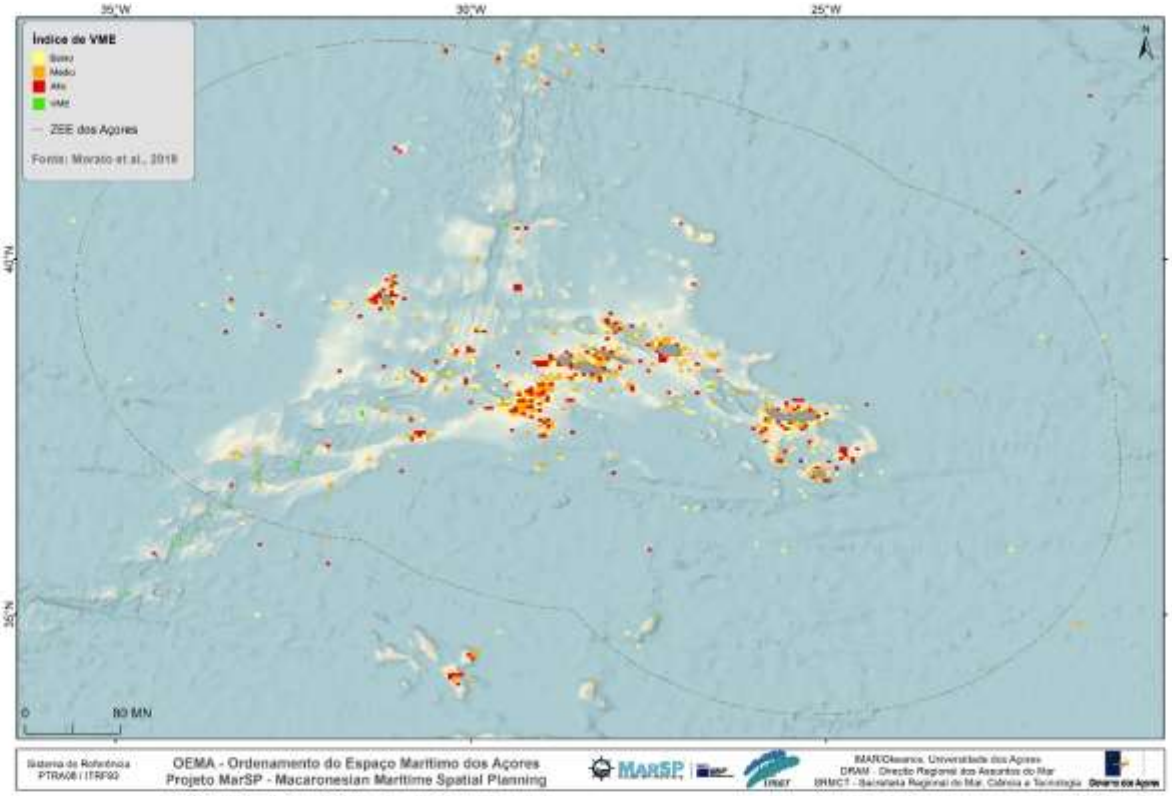
Raster Dataset: 5000m (219.38 KB)

Year: 2019

Keywords: vulnerable marine ecosystems, deep-sea, multi-criteria assessment, cold-water corals, deep-sea sponges

Summary: This map shows Vulnerable Marine Ecosystem (VME) score, based on a multi-criteria assessment method to evaluate how likely a given area of seafloor represents a VME.

VME Score in the Azores



Description: Vulnerable marine ecosystem (VME) bona fide habitats identified in the ICES VME database received the maximum "VME index" of 5. The final "VME index" for each remaining record was calculated based on the VME indicator score and the abundance score. In the current version of the MCA we gave 90% weight to the "VME indicator score" and 10% weight to the abundance score. A low weighting was assigned to the abundance score because of the limited number of records where such information is available, and because there is much uncertainty regarding encounter thresholds when little is known about how VMEs abundances and vulnerabilities have been estimated (ICES, 2012).

After assigning a VME index to each VME indicator record, the results were then aggregated to a grid cell of 0.05 degrees × 0.05 degrees. For each cell, the maximum VME index value was retained as the overall value for that cell. This was to prevent down-weighting of important records by less important records as would happen if, for example, the median or the mean value of a cell was used. It was therefore acknowledged that some cells would have high scores due to a single high scoring record even when other records in that cell may have a low score. This approach was viewed as consistent with the precautionary approach.

The final outcome was presented as VME habitat for these grid cells containing bona fide records and as three nominal categories of “VME index” scores, indicating the likelihood of encountering a VME in the assessed grid cells. Thresholds were computed using the Jenks natural breaks classification method (Jenks, 1967).

URL: https://www.frontiersin.org/articles/10.3389/fmars.2018.00460/full

Credits: IMAR/Okeanos. University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.134665 East -20.205616

North 43.232891 South 33.240923

Citation Contacts:
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
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XY SCALE 450445547.3910538
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Z SCALE 10000
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XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
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3.9.2. VME Confidence

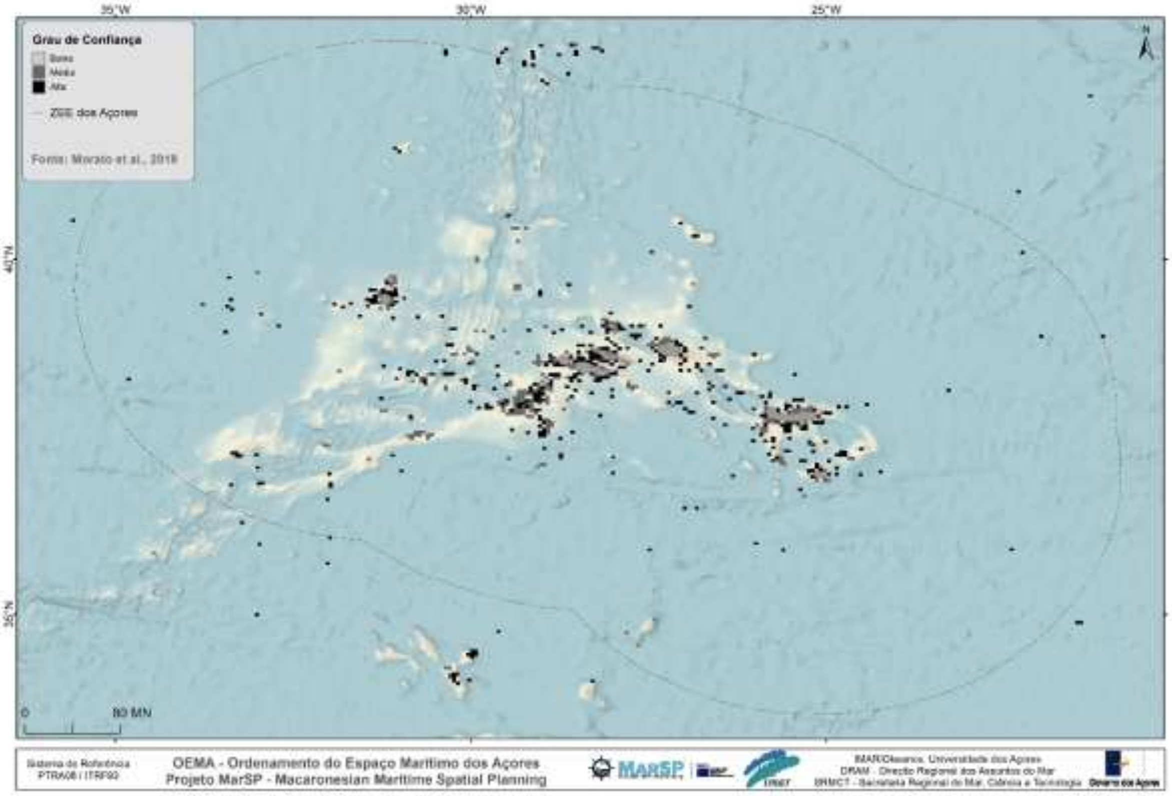
Raster Dataset: 5000m (219.38 KB)

Year: 2019

Keywords: vulnerable marine ecosystems, deep-sea, multi-criteria assessment, cold-water corals, deep-sea sponges, confidence.

Summary: This map shows Vulnerable Marine Ecosystem (VME) confidence, based on a multi-criteria assessment method to evaluate how likely a given area of seafloor represents a VME.

VME Confidence in the Azores



Description: To account for data uncertainty such as data quality issues and the varying degree of knowledge regarding each cell (i.e., how well it has been surveyed), we developed a data confidence index similar to the ones elaborated by Wallace et al. (2011). This index served as a measure of confidence in the "VME index" scores assigned to individual grid cells and was calculated independently of the "VME index." The "Confidence index" was not calculated for bona fide VME habitats identified in the ICES VME database where a confidence index of one was allocated.

Two measures are usually incorporated in such indices (Wallace et al., 2011; Taranto et al., 2012): data quality and data deficiency. We considered using a measure of data deficiency for each grid cell but did not implement that measure as data deficiency is being partially covered in the data quality measure. Therefore, data quality here reflects the origin and nature of the collected data and was divided into three categories: low (scored as 0), medium (scored as 0.5), and high (scored as 1) data quality. The high data quality category highlights cells with information derived from scientific visual surveys, sampled by many independent surveys (>5 surveys), over a long time period (>10 years), and where the most recent record is recent (<10 years) and thus giving an idea if the VME is still present. Low quality data refers to a VME index derived from a poorly sampled grid cell (<3 surveys), where the presence of a VME had been somehow inferred, sampled for only a short period (<5 years) and a long time ago (>30 years). Consequently, four distinct criteria were used for estimating the data "Confidence index".

URL: https://www.frontiersin.org/articles/10.3389/fmars.2018.00460/full

Credits: IMAR/Okeanos. University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -36.134665 East -20.205616

North 43.232891 South 33.240923

Citation Contacts:
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Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details
Projected coordinate system
Well-known identifier 32626
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4. Inventory of Spatial Data Sets: Pressures and Impacts of Human Activities on Ecosystems

The collection of topics about pressures and impacts of human activities in the Azorean Sea includes information about the impact of deep-water longline fishing on epibenthic organisms and specifically on cold-water corals.

Topic	Spatial Data Set	Spatial Data Type	Year (Last update)
Impact of Deep-water Longline Fishing	Deep-water Longline Fishing Impact on Vulnerable Marine Ecosystems: Epibenthic Organisms	Raster	2014
	Deep-water Longline Fishing Impact on Vulnerable Marine Ecosystems: cold-water corals	Raster	2014

Table 4. Spatial Data Sets of Pressures and Impacts of Human Activities on Ecosystems.

4.1. Impact of Deep-water Longline Fishing: Deep-water Longline Fishing Impact on Vulnerable Marine Ecosystems: Epibenthic Organisms

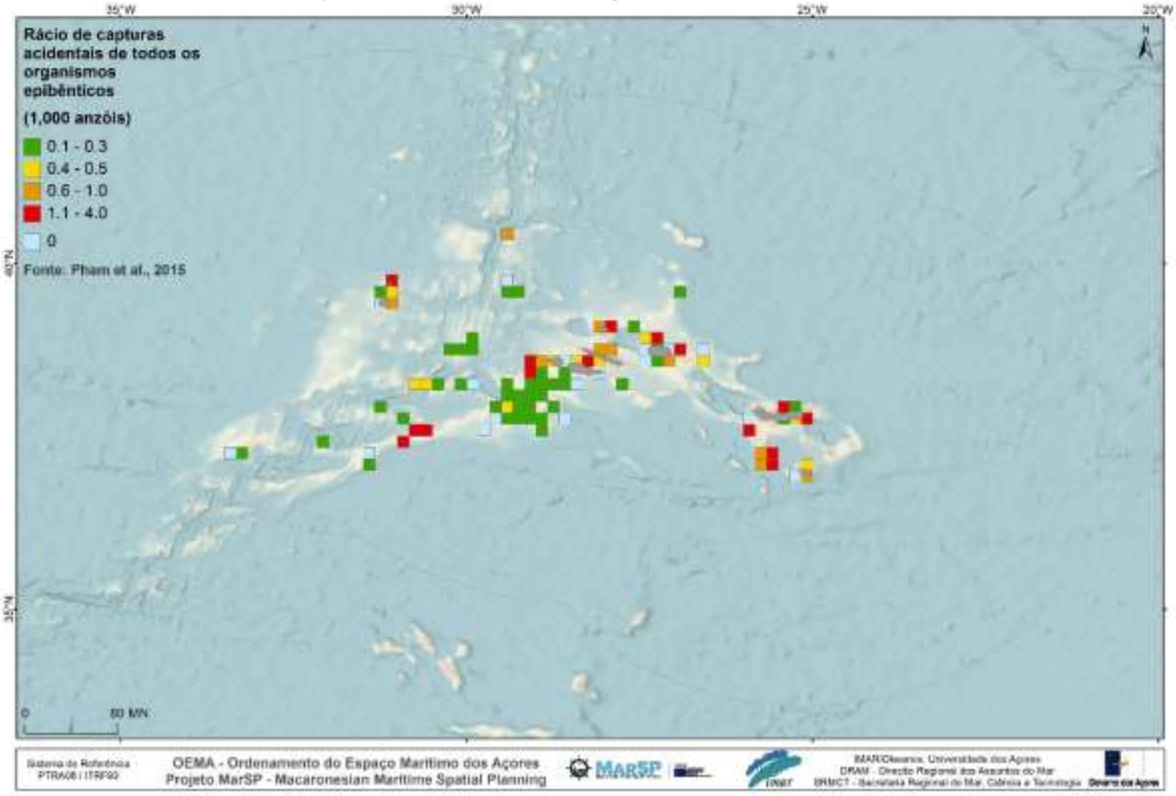
Shapefile (polygon): 1:1 000 000

Year: 2014

Keywords: Azores, VME, Epibenthic Organisms, Impact, Commercial activities, Bottom trawl fishing.

Summary: This layer provides geographic information related to the spatial distribution of fishing effort and bycatch of epibenthic organisms in deep-sea bottom longline sets estimated from commercial activities and research cruises in the Azores.

Bycatch of all benthic organisms in the Azores



Description: Spatial distribution of fishing effort and bycatch of epibenthic organisms in deep-sea bottom longline sets estimated from commercial activities and research cruises in the Azores. Bycatch rates were standardized with General Additive Models.

Bottom trawl fishing threatens deep-sea ecosystems, modifying the seafloor morphology and its physical properties, with dramatic consequences on benthic communities. Therefore, the future of deep-sea fishing relies on alternative techniques that maintain the health of deep-sea ecosystems and tolerate appropriate human uses of the marine environment. In this study, we demonstrate that deep-sea bottom longline fishing has little impact on vulnerable marine ecosystems, reducing bycatch of cold-water corals and limiting additional damage to benthic communities. We found that slow-growing vulnerable species are still common in areas subject to more than 20 years of longlining activity and estimate that one deep-sea bottom trawl will have a similar impact to 296–1,719 longlines, depending on the morphological complexity of the impacted species. Given the pronounced differences in the magnitude of disturbances coupled with its selectivity and low fuel consumption, we suggest that regulated deep-sea longlining can be an alternative to deep-sea bottom trawling.

Bycatch rates of epibenthic organisms in deep-sea bottom longline were standardized with General Additive Models.

Reference: Pham, C., Diogo, H., Menezes, G. et al. Deep-water longline fishing has reduced impact on Vulnerable Marine Ecosystems. Sci Rep 4, 4837 (2015) doi:10.1038/srep04837

Credits: IMAR/Okeanos. University of the Azores. University of British Columbia. "Fisheries Centre. Aquatic Ecosystems Research Laboratory"

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-33.496772	East	-24.996772
North	40.503647	South	36.836980

Citation Contacts:
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Spatial Reference:
* TYPE Geographic
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* Coordinate reference details Geographic coordinate system
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High precision true
Left longitude -180
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4.2. Impact of deep-water Longline Fishing: Deep-water Longline Fishing Impact on Vulnerable Marine Ecosystems: Cold-Water Corals

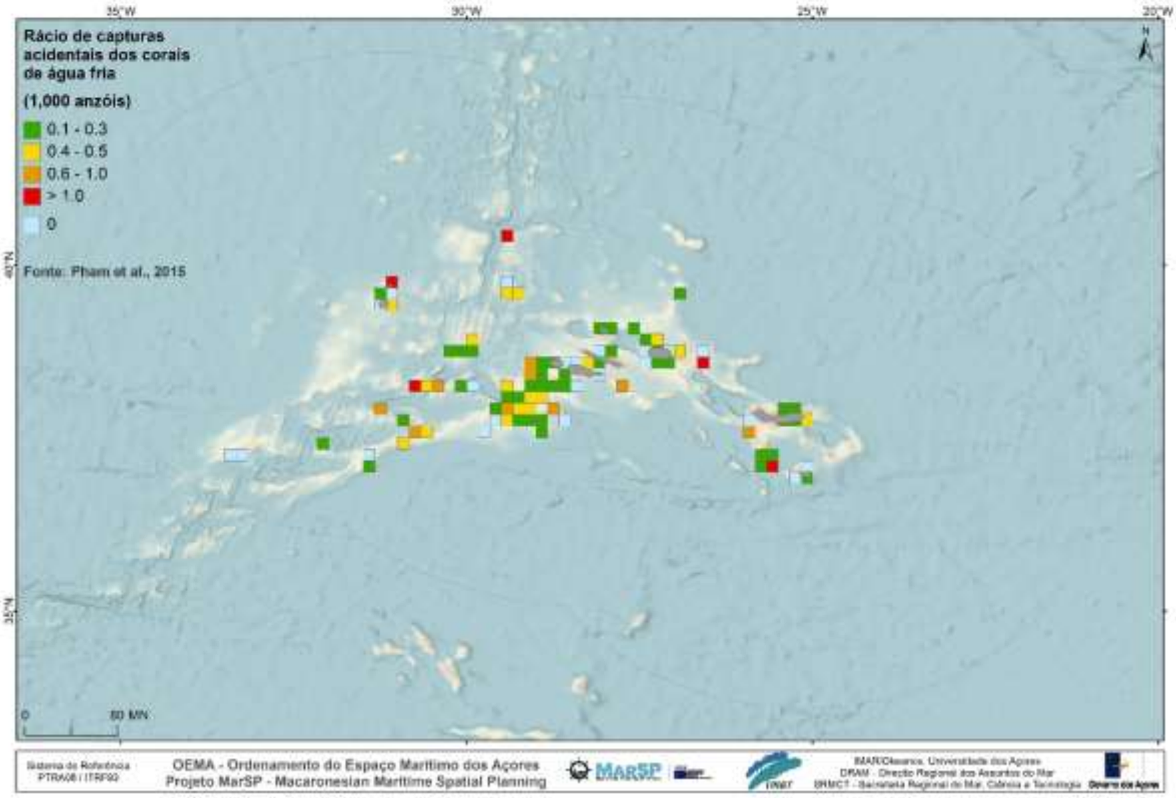
Shapefile (polygon): 1:1 000 000

Year: 2014

Keywords: Azores Islands, VME, CWC, Impact, Commercial activities, Bottom trawl fishing.

Summary: This layer provides geographic information related to the spatial distribution of fishing effort and bycatch of cold-water corals in deep-sea bottom longline sets estimated from commercial activities and research cruises in the Azores.

Bycatch of cold-water corals in the Azores



Description: Spatial distribution of fishing effort and bycatch of cold-water corals in deep-sea bottom longline sets estimated from commercial activities and research cruises in the Azores. Bycatch rates were standardized with General Additive Models.

Bottom trawl fishing threatens deep-sea ecosystems, modifying the seafloor morphology and its physical properties, with dramatic consequences on benthic communities. Therefore, the future of deep-sea fishing relies on alternative techniques that maintain the health of deep-sea ecosystems and tolerate appropriate human uses of the marine environment. In this study, we demonstrate that deep-sea bottom longline fishing has little impact on vulnerable marine ecosystems, reducing bycatch of cold-water corals and limiting additional damage to benthic communities. We found that slow-growing vulnerable species are still common in areas subject to more than 20 years of longlining activity and estimate that one deep-sea bottom trawl will have a similar impact to 296–1,719 longlines, depending on the morphological complexity of the impacted species. Given the pronounced differences in the magnitude of disturbances coupled with its selectivity and low fuel consumption, we suggest that regulated deep-sea longlining can be an alternative to deep-sea bottom trawling.

Bycatch rates of cold-water corals in deep-sea bottom longline were standardized with General Additive Models.

Reference: Pham, C., Diogo, H., Menezes, G. et al. Deep-water longline fishing has reduced impact on Vulnerable Marine Ecosystems. Sci Rep 4, 4837 (2015) doi:10.1038/srep04837

Credits: IMAR/Okeanos. University of the Azores. University of British Columbia. "Fisheries Centre. Aquatic Ecosystems Research Laboratory"

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -33.496772 East -24.996772
North 40.503647 South 36.836980

Citation Contacts:
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CONTACT'S POSITION Marine Biologist Researcher
CONTACT'S ROLE point of contact
E-MAIL ADDRESS lmcrod@gmail.com

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Z TOLERANCE 0.001
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High precision true
Left longitude -180
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5. Inventory of Spatial Data Sets: Uses and Human Activities

The collection of topics about uses and human activities in the Azorean Sea includes information about spatial distribution of several types of uses in the Region. Information about fishing effort by type of fishing gear, types of fishing techniques and infrastructures such as scientific observatories and submarine cables can be found here.

Topic	**Spatial Data Set**	**Spatial Data Type**	**Year (last update)**
Tuna fisheries: Pole-and-line technique	Tuna fisheries: Pole-and-line technique	Raster	2012
Pelagic longline	Azorean fisheries	Raster	2012
	Portuguese mainland fisheries	Raster	2012
	Madeiran fisheries	Raster	2012
	European fisheries	Raster	2012
Bottom longline	Bottom longline	Raster	2012
Infrastructures/Scientific Observatories	Scientific Observatories	Vectorial	2014
Infrastructures/Submarine cables	Submarine cables	Vectorial	2019

Table 5. Spatial Data Sets of Uses and Human Activities.

5.1. Tuna fisheries: Pole-and-line technique

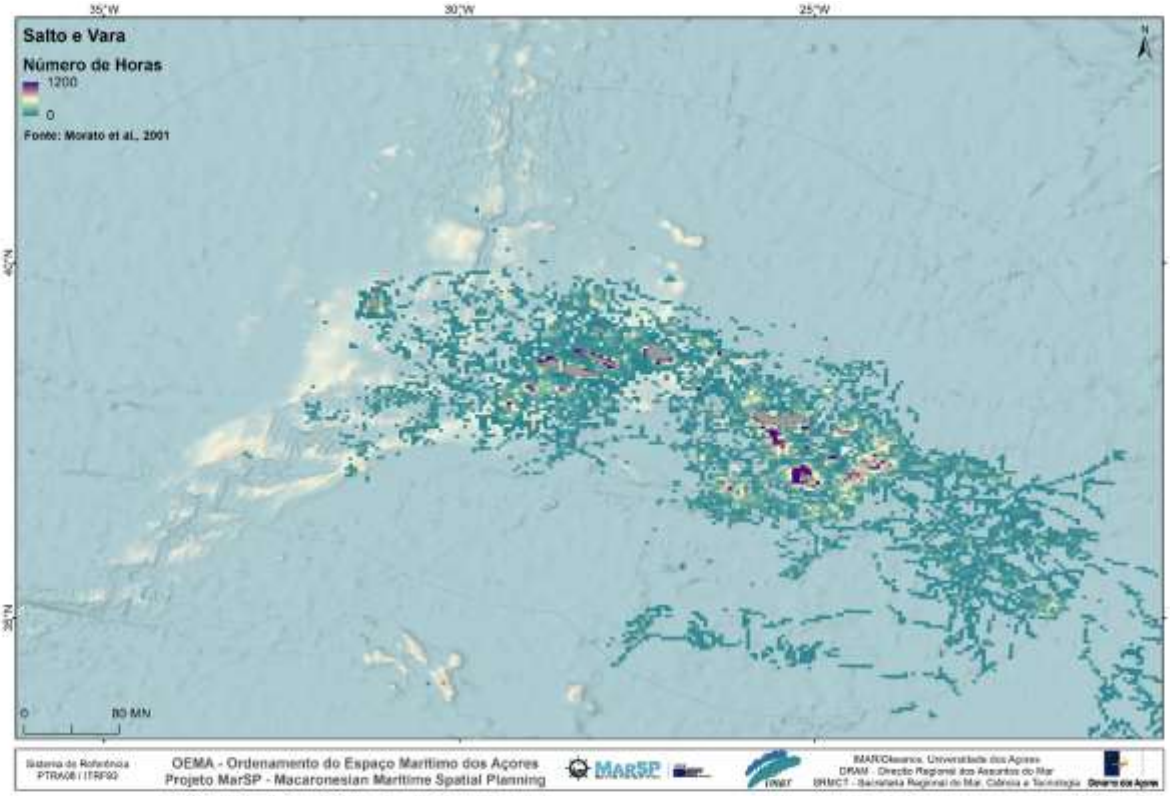
Raster Dataset: 5000m (326.81 KB)

Year: 2012

Keywords: Azores, pole-and-line, tuna, economy, fisheries, fishing effort, ocean

Summary: This layer provides geographic information related to the fishing effort in the Azorean sea by the tuna pole-and-line fishing technique. Fishing effort data was estimated as the sum of timediff.

Tuna fisheries: Pole-and-line technique



Description: Pole and line tuna fishery is one of the most important fisheries in the Azores with reported landings of about 14,000 tonnes in 2010. The importance of this fishery to the total catch is highly variable from year to year, possibly due to changes in tuna abundance and in migration routes (Morato et al., 2001). The tuna fishing generally concentrates around the islands, especially around the central and eastern groups of the archipelago, and around offshore seamounts (Silva et al., 2002; Dâmaso, 2007; Morato et al., 2008b). All tuna fishing vessels operating in the Azores use pole-and-line, usually with live bait and water spray. The fishery usually lasts from April to October, the period when the tuna migrates through the region. A pole and line fishing trip last on average 5–6 days (Silva et al., 2002). The fishing activity starts in the early morning, with fishermen searching for tuna schools with binoculars and using seabirds or floating objects as sighting cues. Upon encountering a school, the water spray is activated, and the live bait is thrown into the water to attract the tunas. Small pelagic fishes may sometimes be used to bait the hooks (Dâmaso, 2007). The number of fishing events per day varies greatly depending on the tuna abundance and size of the schools encountered. The duration of a fishing event and the number of fishing poles (or lines) used were found to be highly variable and poorly correlated with the total tuna caught (Silva et al., 2002). Successful fishing events may last up to 16 h but the average duration is about 25min (Silva et al., 2011). Baitfish is captured by the tuna vessels themselves, using small purse seines or lift nets depending on the seasons/species. Silva et al. (2011) state that blue jack mackerel are mainly caught with purse seine nets that are 250 m long and 10–15 m in depth with a mesh size of 30–40 mm. Generally, fishing for blue jack mackerel occurs at night in 6 to 30 metres of water using lights and chum, while fishing for sardine occurs during the day in 2 to 20 metres of water. On occasion bait catches are made in the open ocean.

The purpose of this data is to show the fishing effort related to the pole-and-line fishing technique in the Azores, inside the EEZ. On this raster is represented the fishing effort of tuna pole-and-line technique in the Azores Islands. This PaL fishing effort is based on VMS analyses. The data units are a sum of time spent in each cell in hours. The period of time is from 07/3/2002 to 30/12/2010.

Credits: IMAR/DOP (Department of Oceanography and Fisheries). University of the Azores. Morato et al., unpublished data (MapGES, ATLAS, CoralFish).

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy"

Extent:

West	-38.979591	East	-18.079113
North	44.371097	South	32.726851

Citation Contacts:
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
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E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
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* PROJECTION WGS_1984_UTM_Zone_26N
Projected coordinate system
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Y ORIGIN -9998100
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Z ORIGIN -100000
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Z TOLERANCE 0.001
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High precision true
Latest well-known identifier 32626
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5.2. Pelagic longline

Raster Dataset Series (4 Models): 4600m (561.15 KB)

The pelagic longline is defined as a series of baited hooks regularly attached to mainline suspended from buoys close to the sea surface. Longlines can be many kilometres long and carry thousands of hooks. The surface longline is very effective in catching swordfish and blue shark. The most common gear used in the Azores is the Spanish type (Ferreira et al., 2011), which consists of a multifilament mainline on which 11 m branch lines are attached successively with hooks at a fixed distance of 45 m (Figure 10). Fishing campaigns of the larger vessels can last for about a month from May/June to December. These large vessels deploy an average of 2,500 hooks per set and extend their fishing areas outside the Exclusive Economic Zone (EEZ) of the Azores (Ferreira et al., 2001).

The purpose of this data is to show the fishing effort related to the pelagic longline fishing technique in the Azores, inside the EEZ. On this raster is represented the fishing effort of the pelagic longline technique in the Azores Islands fisheries by fishermen from 4. This PLL fishing effort is based on VMS analyses. The data units are a sum of time spent in each cell in hours. The period of time is from 2002 to 2010.

In this dataset, there are information about the fishing effort in the Azorean sea using pelagic longline fishing by the following fisheries:

- Azorean fisheries;
- Portuguese mainland fisheries;
- Madeiran fisheries;
- European fisheries.

5.2.1. Azorean fisheries

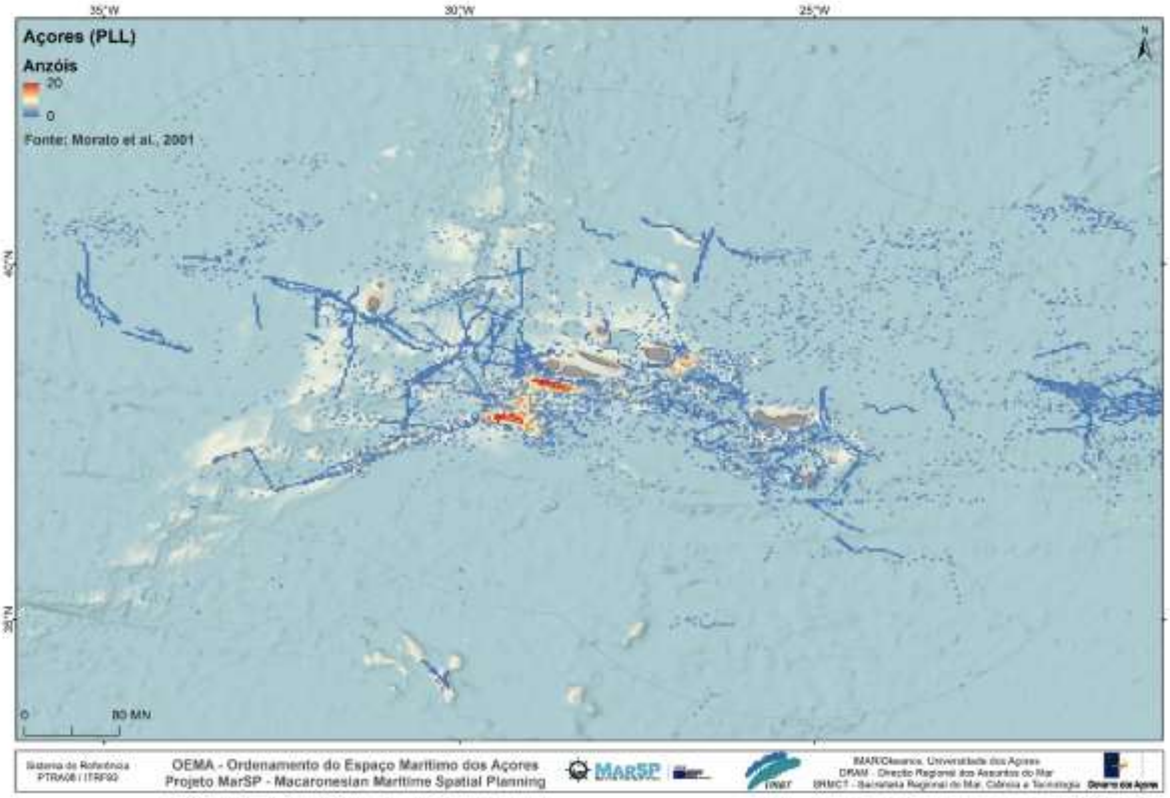
Raster Dataset: 4600m (561.15 KB)

Year: 2012

Keywords: Azores, Azorean fisheries, PLL, bottom, economy, fisheries, fishing effort, ocean

Summary: This layer provides geographic information related to the fishing effort by the Azorean fisheries in the Azorean sea by Azores fleet using "Pelagic Longline" fishing. Fishing effort data was based on the sum of timediff.

Pelagic longline: Azorean fisheries



Credits: IMAR/Okeanos. University of the Azores. Morato et al., unpublished data (2020, MapGES, ATLAS, CoralFish)

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.324706	East	-19.390740
North	43.863187	South	33.151578

Citation Contacts:
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CONTACT'S ROLE Principal Investigator
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Spatial Reference:
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* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details Projected coordinate system
Well-known identifier 32626
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High precision true
Latest well-known identifier 32626
WELL-KNOWN TEXT
PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984", SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree", 0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

5.2.2. Portuguese mainland fisheries

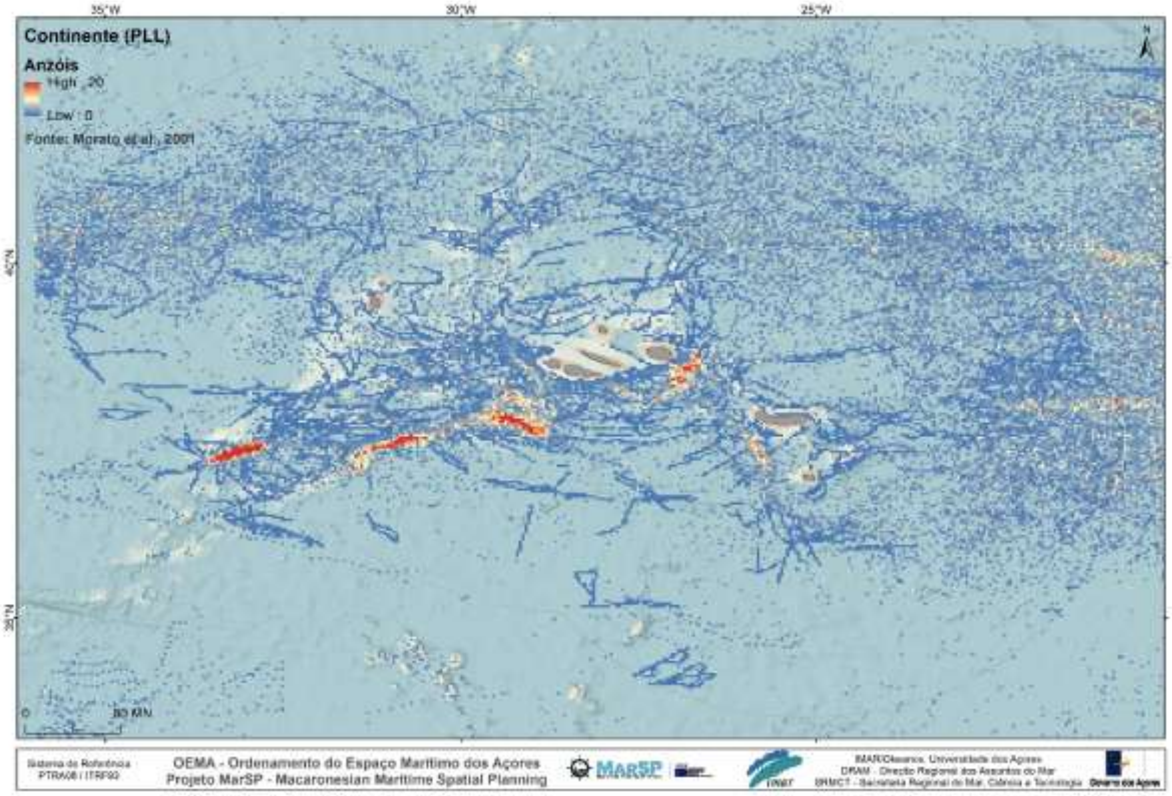
Raster Dataset: 4600m (561.15 KB)

Year: 2012

Keywords: Azores, Portuguese mainland fisheries, PLL, bottom, economy, fisheries, fishing effort, ocean

Summary: This layer provides geographic information related to the fishing effort by the Azorean fisheries in the Portuguese mainland sea by Azores fleet using "Pelagic Longline" fishing. Fishing effort data was based on the sum of timediff.

Pelagic longline: Portuguese mainland fisheries



Credits: IMAR/Okeanos. University of the Azores. Morato et al., unpublished data (2020, MapGES, ATLAS, CoralFish)

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.324706	East	-19.390740
North	43.863187	South	33.151578

Citation Contacts:
INDIVIDUAL'S NAME Telmo Morato
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CONTACT'S POSITION Researcher
CONTACT'S ROLE Principal Investigator
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details Projected coordinate system

Well-known identifier 32626
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Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000

M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
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5.2.3. Madeiran fisheries

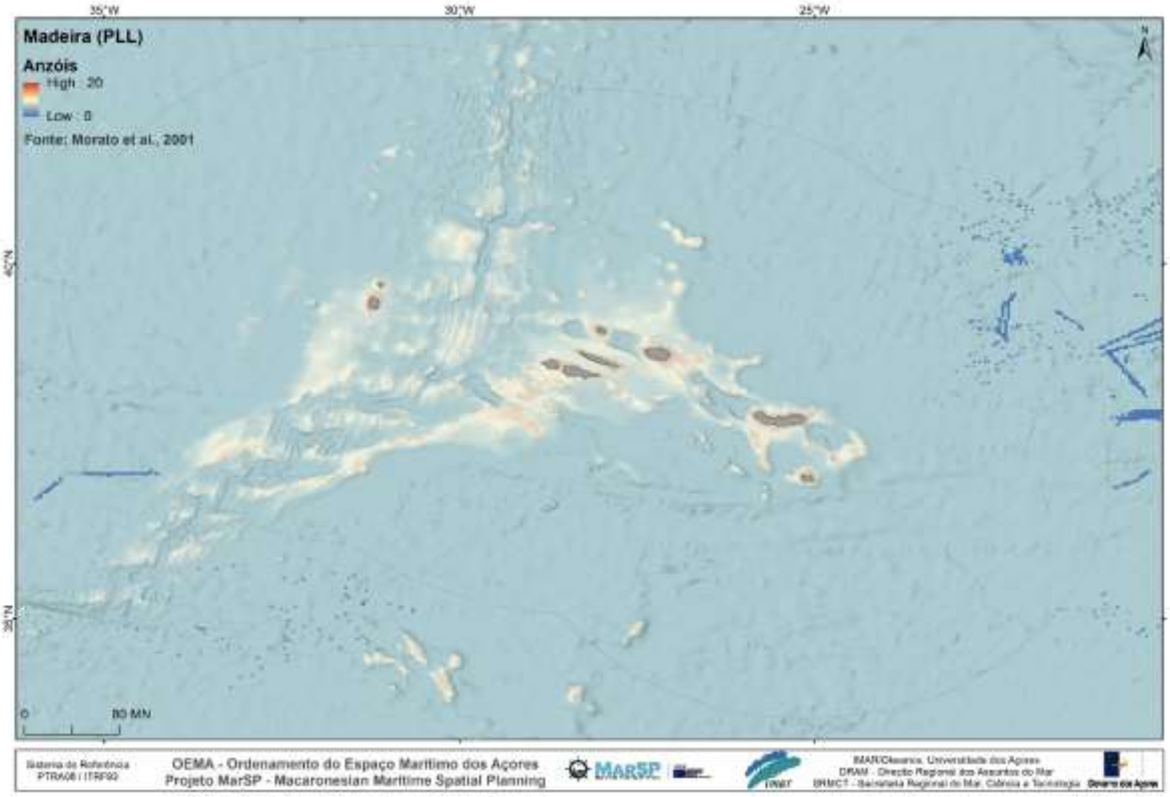
Raster Dataset: 4600m (561.15 KB)

Year: 2012

Keywords: Azores, Madeiran fisheries, PLL, bottom, economy, fisheries, fishing effort, ocean

Summary: This layer provides geographic information related to the fishing effort by the Madeiran fisheries in the Azorean sea by Azores fleet using "Pelagic Longline" fishing. Fishing effort data was based on the sum of timediff.

Pelagic longline: Madeiran fisheries



Credits: IMAR/Okeanos. University of the Azores. Morato et al., unpublished data (2020, MapGES, ATLAS, CoralFish)

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.324706	East	-19.390740
North	43.863187	South	33.151578

Citation Contacts:
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Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
Projected coordinate system
Well-known identifier 32626
X ORIGIN -5120900
Y ORIGIN -9998100
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Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
WELL-KNOWN TEXT
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5.2.4. European fisheries

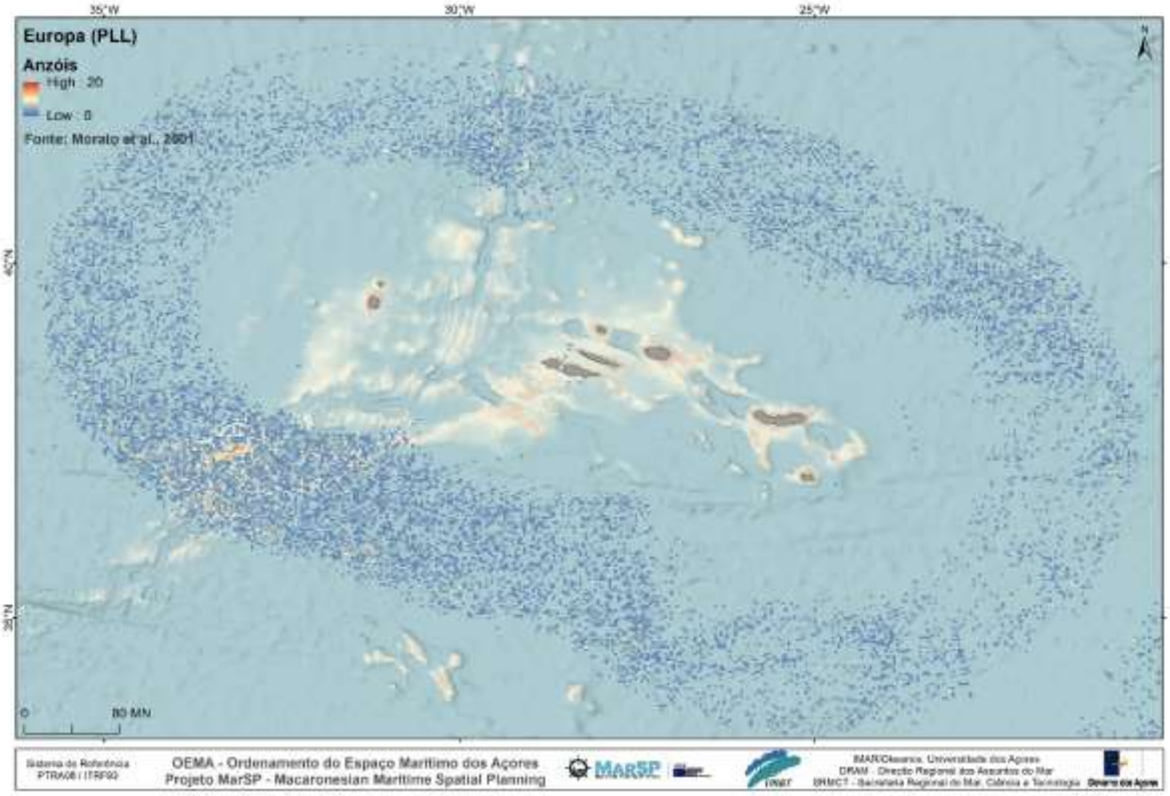
Raster Dataset: 4600m (561.15 KB)

Year: 2012

Keywords: Azores, Azorean fisheries, PLL, bottom, economy, fisheries, fishing effort, ocean

Summary: This layer provides geographic information related to the fishing effort by the European fisheries in the Azorean sea by Azores fleet using "Pelagic Longline" fishing. Fishing effort data was based on the sum of timediff.

Pelagic longline: European fisheries



Credits: IMAR/Okeanos. University of the Azores. Morato et al., unpublished data (2020, MapGES, ATLAS, CoralFish)

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-37.324706	East	-19.390740
North	43.863187	South	33.151578

Citation Contacts:
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Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
* Coordinate reference details Projected coordinate system

Well-known identifier 32626
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Y ORIGIN -9998100
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Z ORIGIN -100000
Z SCALE 10000

M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
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PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984", SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree", 0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

5.3. Bottom longline

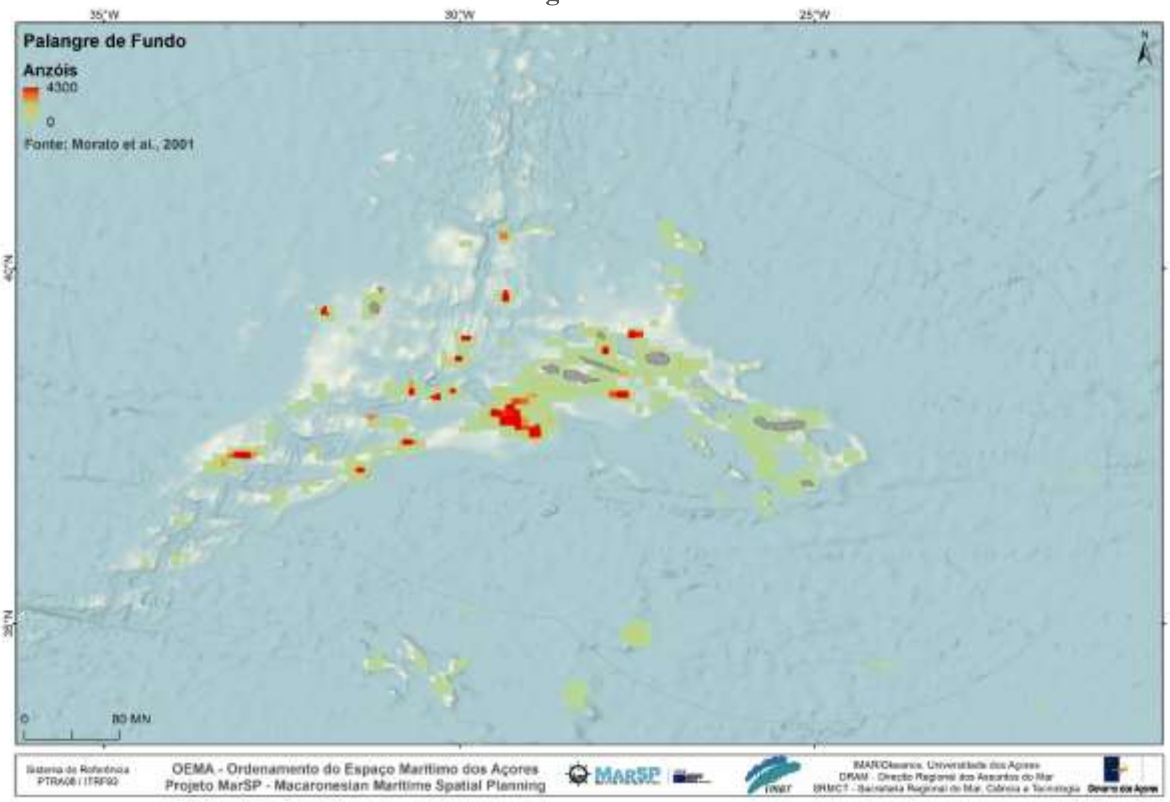
Raster Dataset: 4600m (561.15 KB)

Year: 2012

Keywords: Azores, bottom longline, handline, bottom, economy, fisheries, fishing effort, ocean

Summary: This layer provides geographic information related to the fishing effort in the Azorean sea by the "Bottom Longline" fishing technique. Fishing effort data was the sum of timediff.

Bottom longline in the Azores



Credits: IMAR/Okeanos. University of the Azores. Morato et al., unpublished data (2020, MapGES, ATLAS, CoralFish)

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy"

Extent:

West -37.324706 East -19.390740
North 43.863187 South 33.151578

Citation Contacts:
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CONTACT'S ROLE Principal Investigator
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Point of Contact:
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CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_UTM_Zone_26N
Projected coordinate system
Well-known identifier 32626
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Y ORIGIN -9998100
XY SCALE 450445547.3910538
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 32626
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PROJCS["WGS_1984_UTM_Zone_26N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Transverse_Mercator"],PARAMETER["False_Easting",500000.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",-27.0],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_Of_Origin",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",32626]]

5.4. Scientific Observatories in the Azores

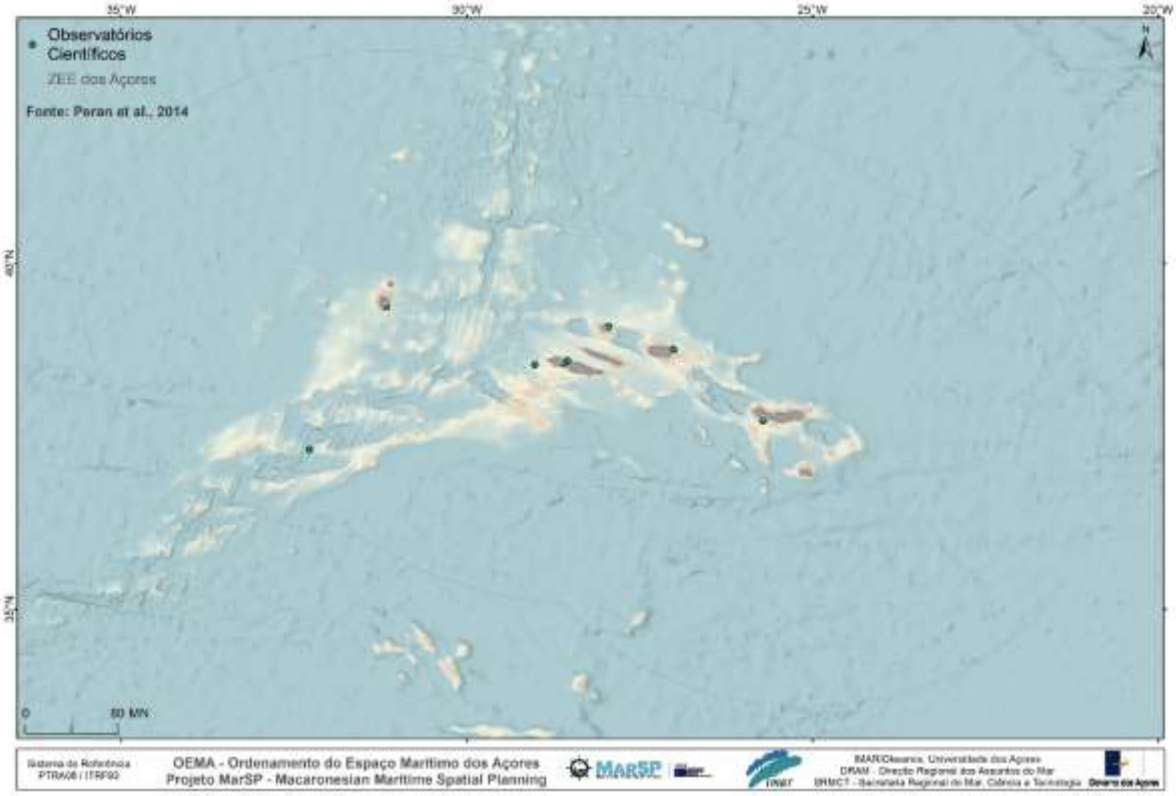
Shapefile: Points (1:5 000 000)

Year: 2014

Keywords: Azores, Climaat, Condor, Lucky Strike, observatories, OceanaLab, science, station

Summary: This layer provides geographic information related to the geographic position of specific scientific stations, where scientists of the University of the Azores obtain relevant information about the biology and ecology in the Azorean Sea.

Scientific observatories in the Azores



Description: This shapefile identifies the different scientific stations around the Azores region. The scientific stations represented on this layer are the following:-Lucky Strike. This scientific station provides important biology, environmentally and ecology information related to the Hydrothermal Vents structures in the Azorean sea.- Condor-Project. Condor observatory is an underwater multidisciplinary laboratory for seamount research, implemented on the Condor seamount. The integration of many different aspects of the ecosystem, make a significant contribution to the understanding of seamount ecological structure and functioning, from the sea surface down to the seafloor. (www.condor-project.org)- OceanaLab. The objectives of this scientific station are: 1. Determine pH-induced changes in the diversity and functioning of microbial communities inhabiting sediments. 2. Determine the effects of decreasing pH on chemical and biogenic dissolution rates of biological substrates common in the Azores region. 3. Evaluate the effect of decreasing pH on the ecologically-important coral species *Antipathella wollastoni* and its symbiotic assemblages. (oceana-lab.wix.com)- Climaat Project. The Climaat Project is composed by 5 different meteorological stations located around the Azorean sea. Their main objective is to collect environmental and climatological data about the Azorean Sea and the Azores Islands. (http://www.climaat.angra.uac.pt/)

Credits: IMAR/Okeanos. University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy"

Extent:

West	-37.324706	East	-19.390740
North	43.863187	South	33.151578

Citation Contacts:
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CONTACT'S POSITION Biologist & GIS Technician
CONTACT'S ROLE Author

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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Geographic
* Geographic coordinate reference GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier 4326
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Y ORIGIN -400
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M SCALE 10000
XY TOLERANCE 8.983152841195215e-09
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Left longitude -180
Latest well-known identifier 4326
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5.5. Submarine cables

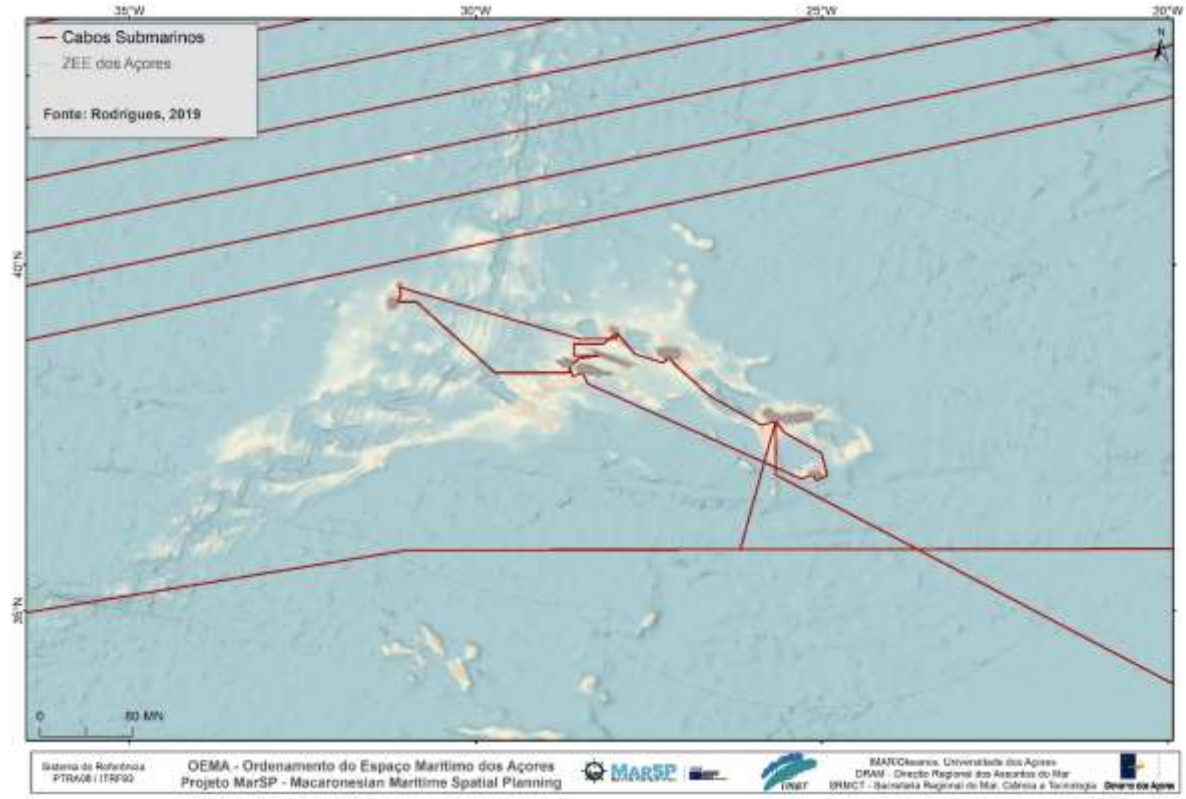
Shapefile: Points (1:5 000 000)

Year: 2019

Keywords: Azores, communication, human uses, seafloor, submarine cables

Summary: This layer provides geographic information related to the submarine cables in the North Atlantic Ocean, specifically in the Azores.

Submarine cables in the Azores



Description: The information represented on this layer has been extracted from the "TeleGeography's interactive Submarine Cable Map". This specific map that represents the global active submarine cables on the seafloor of the oceans is based on Global Bandwidth research. Associated with each cable there is important information like: cable's name, ready for service (RFS) date, cable's length, owners, website and landing points. It is remarkable that the cables shown on this layer include international cables with a maximum upgradeable capacity of at least 5 Gbps. The submarine cables do not reflect the physical cable exactly location. Source: http://www.submarinecablemap.com/#/ Bandwidth research: TeleGeography's Global Bandwidth Research Service is the world's most comprehensive and authoritative source of data analysis for long-haul networks and the undersea cable market.

Credits: IMAR/Okeanos. University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy"

Extent:

West -41.000000 East -17.000000
North 49.000000 South 28.000000

Citation Contacts:
INDIVIDUAL’S NAME Luís Rodrigues
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CONTACT’S POSITION Biologist & GIS Technician
CONTACT'S ROLE Author

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CONTACT’S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:

* TYPE   Geographic
* Geographic coordinate reference
GCS_WGS_1984
* Coordinate reference details
Geographic coordinate system
Well-known identifier   4326
X ORIGIN   -400
Y ORIGIN   -400
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Z SCALE   10000
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M SCALE   10000
XY TOLERANCE   8.983152841195215e-09
Z TOLERANCE   0.001
M TOLERANCE   0.001
High precision   true
Left longitude   -180
Latest well-known identifier   4326
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6. Inventory of Spatial Data Sets: Legal Issues

This dataset includes information about spatial distribution of the various legal issues in the region. You can find different types of data as the location of marine protected areas, the main requirements for fishing, the protected areas of international organizations and the main boundaries based on certain rules (such as 200NM of the EEZ).

Topic	**Spatial Data Set**	**Spatial Data Type**	**Year (last update)**
All Protected Areas	All Protected Areas	Vectorial Polygons	2020
Marine Park of the Azores	Marine Park of the Azores	Vectorial Polygons	2019
100 Nautical Miles of the Azorean Sea	100 Nautical Miles of the Azorean Sea	Vectorial Polygons	2019
Special requirements for bottom fishing activity in the Azores	Special requirements for bottom fishing activity in the Azores	Vectorial Polygons	2014
Bottom Trawl Ban in the Azores Islands	Bottom Trawl Ban in the Azores Islands	Vectorial Polygons	2020
Extended Azorean Continental Shelf	Extended Azorean Continental Shelf	Vectorial Polygons	2009
FAO Statistical Areas in the Azores	FAO Statistical Areas in the Azores	Vectorial Polygons	2017
OSPAR Marine Protected Areas	OSPAR Marine Protected Areas	Vectorial Polygons	2016

Table 6. Spatial Data Sets of Legal Issues.

6.1. All Protected Areas

Shapefile: Polygon (1: 1 000 000)

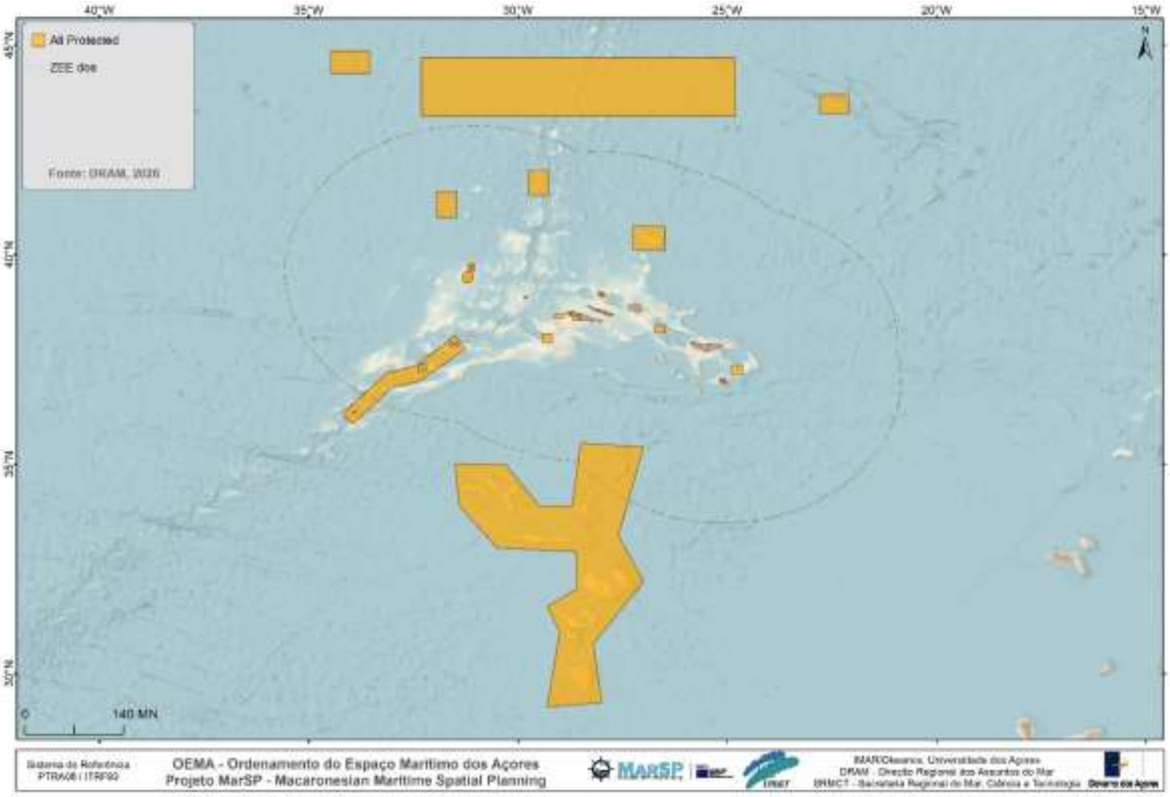
Year: 2020

Keywords: Azores, conservation, environmental management, IUCN, limits, marine protected areas, nature 2000, natural parks, network, protected areas, resource management.

Summary: This resource provides geographic information for the conservation and environmental management of all the protected areas, which are part of the Azores.

It is important to remark that the majority of the protected area are outside the EZZ limits.

All protected areas in the Azores



Description: The Regional Network of the Protected Areas in the Azores was set up by the Azorean regulation "Decreto Legislativo Regional nº 15/2007/A", with the purpose of make a new classification of them according to the "Natura 2000 Network". Natura 2000 applies to "bird sites" and "habitat sites" which are divided into biogeographical regions. And it also applies to the marine environment. The aim of this new network of nature protected areas in the Azores was to integrate the new classification of the IUCN.

The new elements for the natural and maritime parks are the following:

- Nature Reserve;
- Monument Reserve;
- Protected area of habitats/species management;
- Protected area of landscape;
- Protected area of resource management.

Credits: IMAR, Okeanos. University of the Azores; Regional Government of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-34.461180	East	-22.101180
North	44.860668	South	36.217428

Citation Contacts:
ORGANIZATION'S NAME Direção Regional dos Assuntos do Mar (DRAM); IMAR/Okeanos. University of the Azores
E-MAIL ADDRESS: lmcrod@gmail.com

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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE principal investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details
Projected coordinate system
Well-known identifier 3395
X ORIGIN -20037700
Y ORIGIN -30198300
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High precision true
Latest well-known identifier 3395
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6.2. Marine Park of the Azores

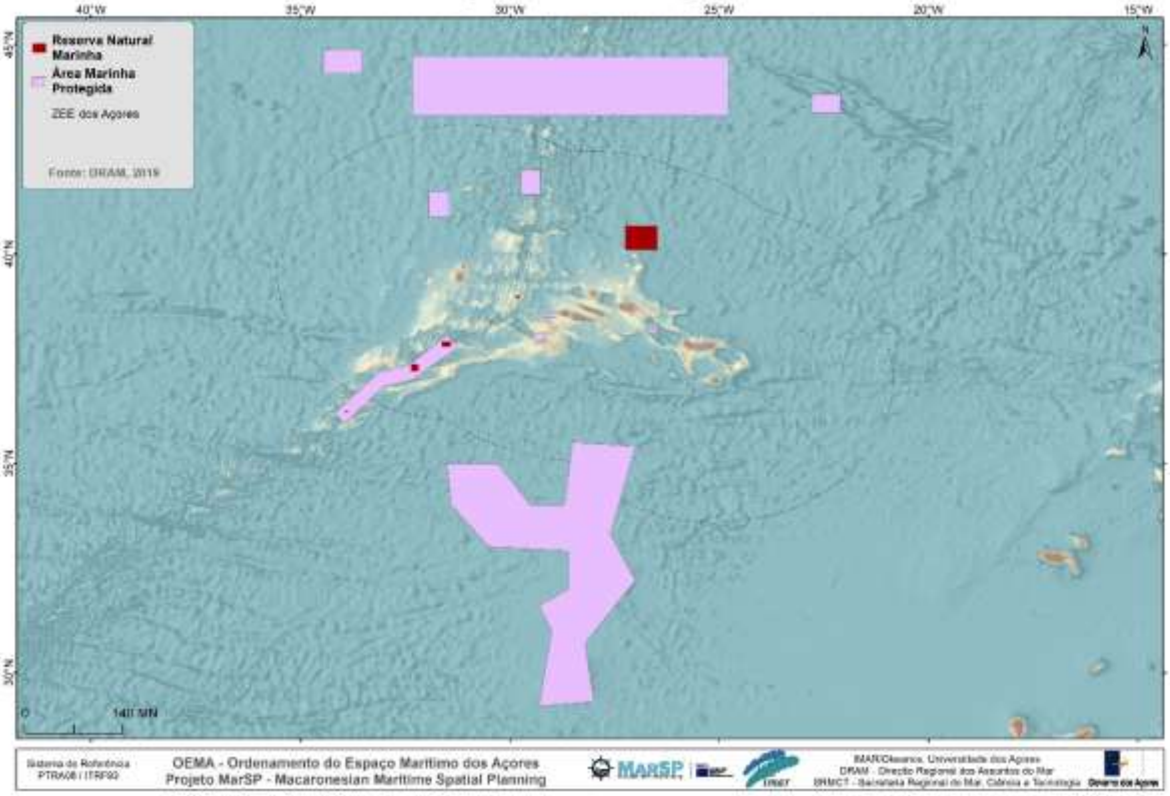
Shapefile: Polygon (1: 1 000 000)

Year: 2019

Keywords: Azores, conservation, environmental management, limits, marine protected areas, protected areas, natural reserves, resource management.

Summary: This resource provides geographic information for the conservation and environmental management: Marine Park of the Azores.

Marine Park in the Azores



Description: The Azores Marine Park (AMP) proposal, developed by the Geographical Information and Territorial Planning Centre (Centro de Informação Geografica e Planeamento Territorial; CIGPT) at University of the Azores (Ponta Delgada), was submitted in 2010 by the Azores Environment Agency to the Azores Parliament and will be implemented upon approval. This is the most recent effort towards establishing a Portuguese legal entity for consolidating and creating a coherent Azorean network of offshore marine protected areas (MPAs). The proposal included seven existing designated MPAs: four offshore habitats located within the Azorean Economic Exclusive Zone (EEZ; Banco Dom João de Castro seamount, Sedlo seamount, Lucky Strike hydrothermal vent field and Menez Gwen hydrothermal vent field), one located beyond the Azorean EEZ (Rainbow hydrothermal vent field), and two Marine Important Bird Areas (North of Corvo Offshore, and North of Corvo and Faial Offshore).

These MPAs had been nominated by various conservation organizations and site-specific legally binding recommendations have been developed. AMP recommendations were created for each site according to strict protection objectives and management objectives adapted from the International Union for Conservation of Nature (IUCN) Protected Area Management Categories. Since its submission, three additional high seas MPAs in areas beyond national jurisdiction and subject to Portuguese continental shelf extension claims (Altair seamount, Antialtair seamount and an area of the Mid-Atlantic Ridge north of the Azores) were nominated in September 2010 by the OSPAR Commission. These MPAs have subsequently been proposed for inclusion in the AMP. With intensifying efforts to protect biodiversity, an increase in offshore Azorean MPAs is likely.

Consequently, the MPA will likely extend its spatial limit to include new high seas MPAs and develop legally binding regulations for each new MPA as an on-going process. The full-scale “one-stop agency” MPA is envisioned to provide a representative offshore MPA network for the Azores that will protect all major ecosystem features in relation to their habitats and species, at an appropriate scale, within and across each bioregion.

With Portaria Nº 68/2019, of 26 September, the Regulation for the exercise of fishing in the maritime zone of the LUSO hydrothermal field was approved. With this Portaria the fishing activity is regulated in the marine area of the LUSO hydrothermal field. Thus, the list of protected marine areas was updated in 2019.

Credits: IMAR, Okeanos. University of the Azores; Regional Government of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West	-34.461180	East	-22.101180
North	44.860668	South	36.217428

Citation Contacts:
ORGANIZATION'S NAME Direção Regional dos Assuntos do Mar (DRAM); IMAR/Okeanos. University of the Azores
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Point of Contact:
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CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE Principal Investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:

*TYPE Projected
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details
Projected coordinate system
Well-known identifier 3395
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 10000
Z ORIGIN -100000
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XY TOLERANCE 0.001
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M TOLERANCE 0.001
High precision true
Latest well-known identifier 3395
WELL-KNOWN TEXT
PROJCS["WGS_1984_World_Mercator",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER ["False_Easting",0.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",0.0],PARAMETER["Standard_Parallel_1",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",3395]]

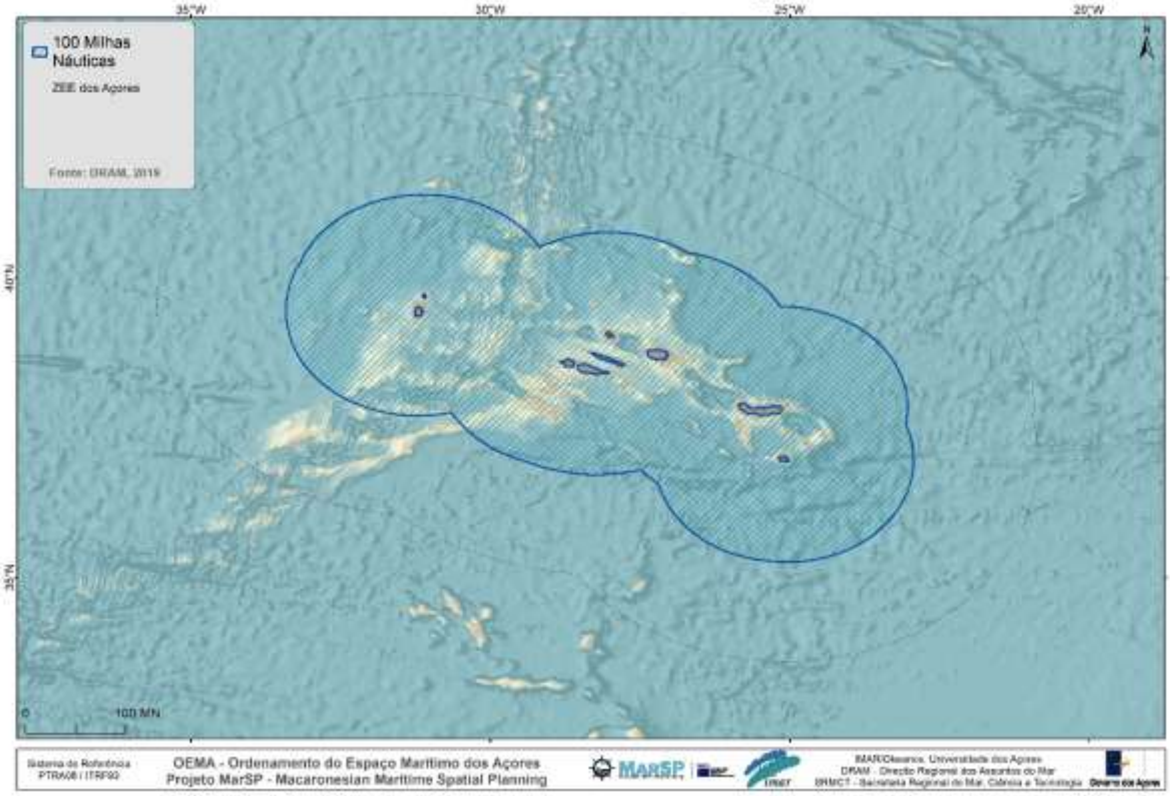
6.3. Nautical Miles (100) of the Azorean Sea

Shapefile: Polygon (1: 1 000 000)

Year: 2019

Keywords: Azores, 100NM, fishing effort, protected area, limits, environmental management, resource management.

100 Nautical Miles of the Azorean Sea



Summary: This layer provides geographic information related to the management of fishing effort of the Azorean Sea with a limit of 100 nautical miles.

Description: The limit of the 100 Nautical Miles of the Azorean Sea was developed by the European regulation Nº 1954/2003. This regulation establishes the criteria and procedures for a system relating to the management of fishing effort in ICES areas V, VI, VII, VII, IX and other CECAF divisions.

"Fishing effort" means the product of the capacity and the activity of a fishing vessel; for a group of vessels it means the sum of fishing effort

In the waters up to 100 nautical miles from the baselines to the Azores, the Member States concerned may restrict fishing to vessels registered in the ports of these islands, except for Community Vessels that traditionally fish in those waters in so far as these do not exceed the fishing effort traditionally exerted (Article 5, Council Regulation (EC) No 1954/2003).

Credits: IMAR, Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -33.416019 East -22.931868
North 41.394536 South 35.256793

Citation Contacts:
ORGANIZATION'S NAME Direção Regional dos Assuntos do Mar (DRAM); IMAR/Okeanos. University of the Azores
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CONTACT'S ROLE principal investigator
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Spatial Reference:

* TYPE Projected
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details
Projected coordinate system
Well-known identifier 3395
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 10000
Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 3395
WELL-KNOWN TEXT
PROJCS["WGS_1984_World_Mercator",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["False_Easting",0.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",0.0],PARAMETER["Standard_Parallel_1",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",3395]]

6.4. Special requirements of bottom fishing activity in the Azores

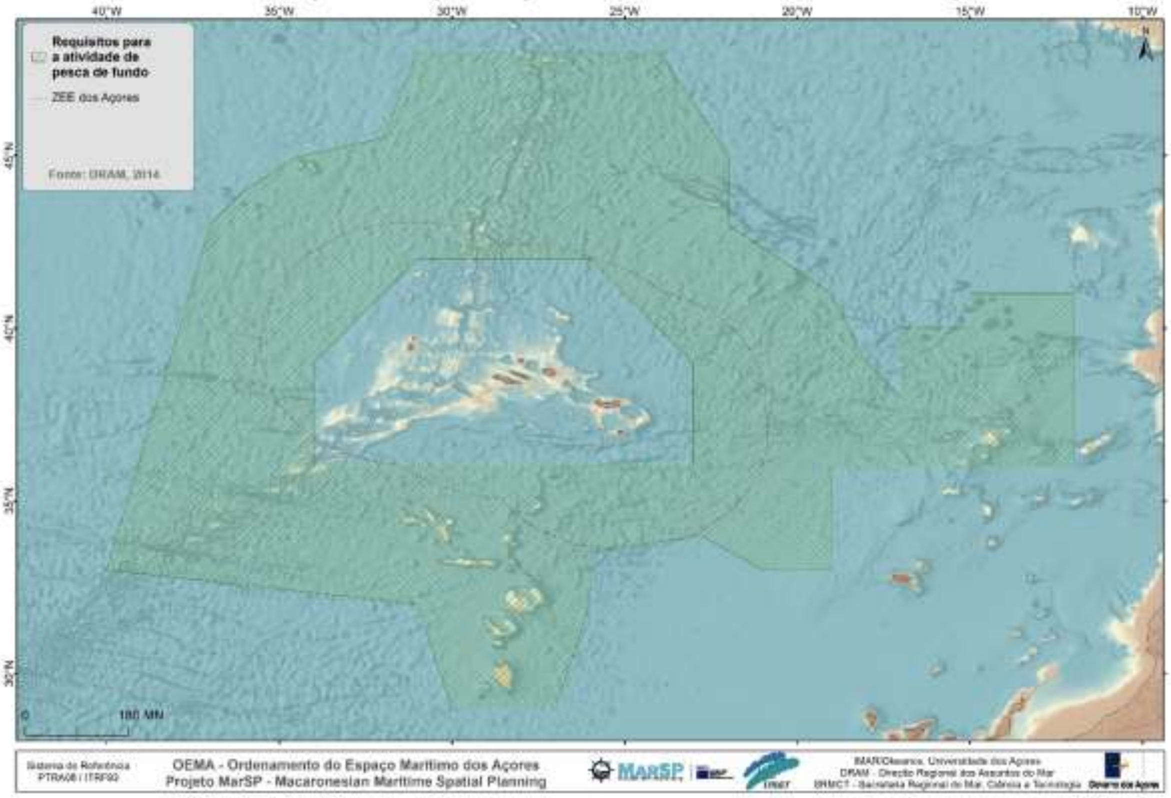
Shapefile: Polygon (1: 1 000 000)

Year: 2014

Keywords: Azores, bottom fishing, law, legal issues, marine resources, requirements, seafloor

Summary: This layer represents geographic information related to the geographic limits for the new requirements of the bottom fishing activity in the Azores.

Area with Special Requirements of bottom fishing activity in the Azores



Description: The Regional Government of the Azores established these geographic limits by the "Portaria nº 114/2014", with the purpose of introducing new requirements of the bottom fishing activity in the Azores. This law establishes the specific requirements for the protection of the seafloor from fishing activities impacts inside these geographic limits, such as:- Fishing techniques allowed in the area- Special requirements for the bottom longline technique in the area- Register and communication about sponge and corals captures.

Credits: IMAR, Okeanos. University of the Azores

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -40.000000 East -12.000000

North 48.000000 South 29.000000

Citation Contacts:

ORGANIZATION'S NAME Direção Regional dos Assuntos do Mar (DRAM); IMAR/Okeanos. University of the Azores
E-MAIL ADDRESS: lmcrod@gmail.com

Point of Contact:

INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
CONTACT'S ROLE principal investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:

* TYPE Projected
* Geographic coordinate reference
GCS_WGS_1984
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details
Projected coordinate system
Well-known identifier 3395
X ORIGIN -20037700
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XY SCALE 149134210.44795552
WELL-KNOWN TEXT
PROJCS["WGS_1984_World_Mercator",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["False_Easting",0.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",0.0],PARAMETER["Standard_Parallel_1",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",3395]]

Z ORIGIN -100000
Z SCALE 10000
M ORIGIN -100000
M SCALE 10000
XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 3395

6.5. Bottom Trawl Ban in the Azores Islands

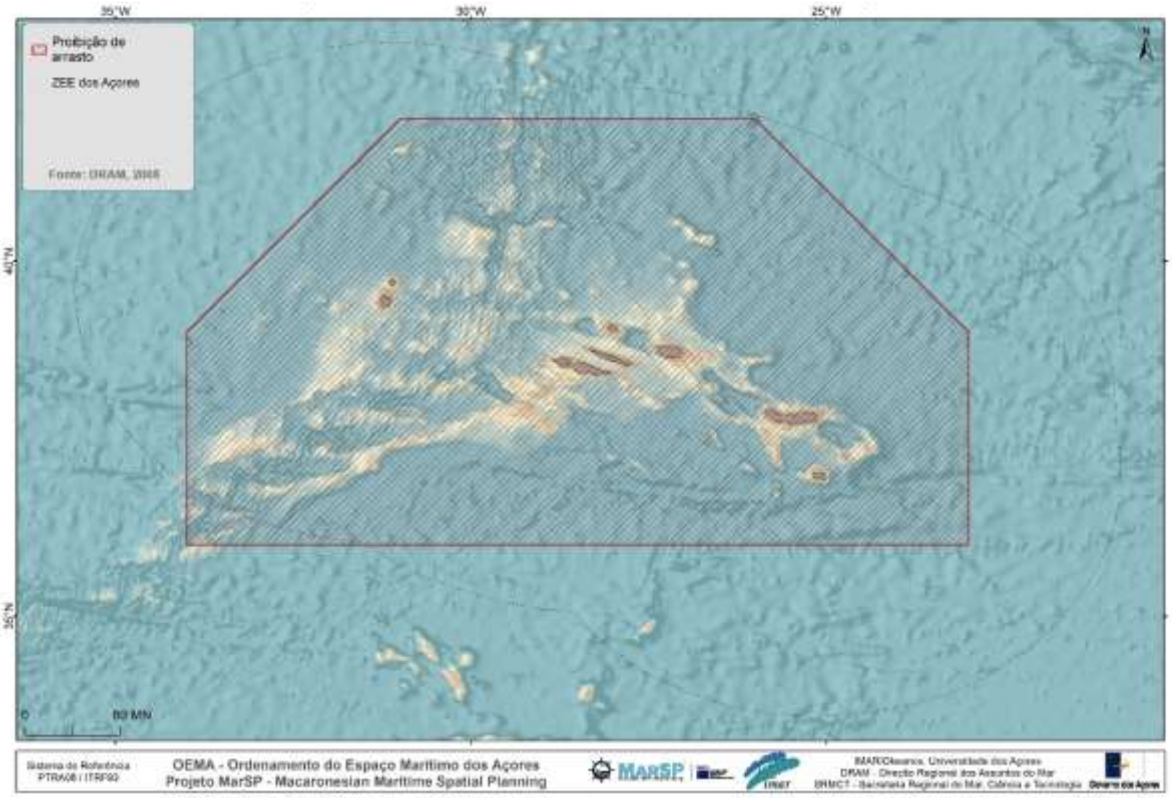
Shapefile: Polygon (1: 1 000 000)

Year: 2020

Keywords: Azores, ban, bottom trawling, fishing, limits, oceans, resource management, trawl

Summary: This layer provides geographic information related to the limits of the "Bottom Trawl Ban in the Azores islands".

Bottom Trawl Ban in the Azores



Description: The limits of the "Bottom Trawl Ban in the Azores islands" were established by The Council Regulation (EC) Nº 1568/2005 of 20 September 2005, amending Regulation (EC) Nº 850/98 as regards the protection of the deep-water coral reefs from the effects of fishing in certain areas of the Atlantic Ocean. According to recent scientific reports of the International Council for the Exploration of the Sea (ICES) highly sensitive deep-water habitats have been found and mapped in the Atlantic, so there is a necessity to ensure the protection of those areas through an extension of the restrictions on the use of demersal gears contained in Regulation (EC) No 850/98.The Council Regulation (EC) Nº 1568/2005set up one extra paragraph: "Vessels shall be prohibited from using any gillnet entangling net or trammel net at depths greater than 200 meters and any bottom trawl or similar towed nets operating in contact with the bottom of the sea in the areas bounded by a line joining the following coordinates:- Area named "Azores”: Latitude 36º 00' N Longitude 23º 00' W Latitude 39º 00' N Longitude 23º 00' W Latitude 42º 00' N Longitude 26º 00' W Latitude 42º 00' N Longitude 31º 00' W Latitude 39º 00' N Longitude 34º 00' W Latitude 36º 00' N Longitude 34º 00' W

Credits: IMAR, Okeanos. University of the Azores; Regional Government of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -34.000000 East -23.000000

North 42.000000 South 36.000000

Citation Contacts:
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
E-MAIL ADDRESS: lmcrod@gmail.com

Point of Contact:
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ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
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CONTACT'S ROLE principal investigator
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details
Projected coordinate system
Well-known identifier 3395
X ORIGIN -20037700
Y ORIGIN -30198300
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Z SCALE 10000
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XY TOLERANCE 0.001
Z TOLERANCE 0.001
M TOLERANCE 0.001
High precision true
Latest well-known identifier 3395
WELL-KNOWN TEXT
PROJCS["WGS_1984_World_Mercator",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["False_Easting",0.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",0.0],PARAMETER["Standard_Parallel_1",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",3395]]

6.6. Extended Azorean Continental Shelf with 200nm Exclusive Economic Zone

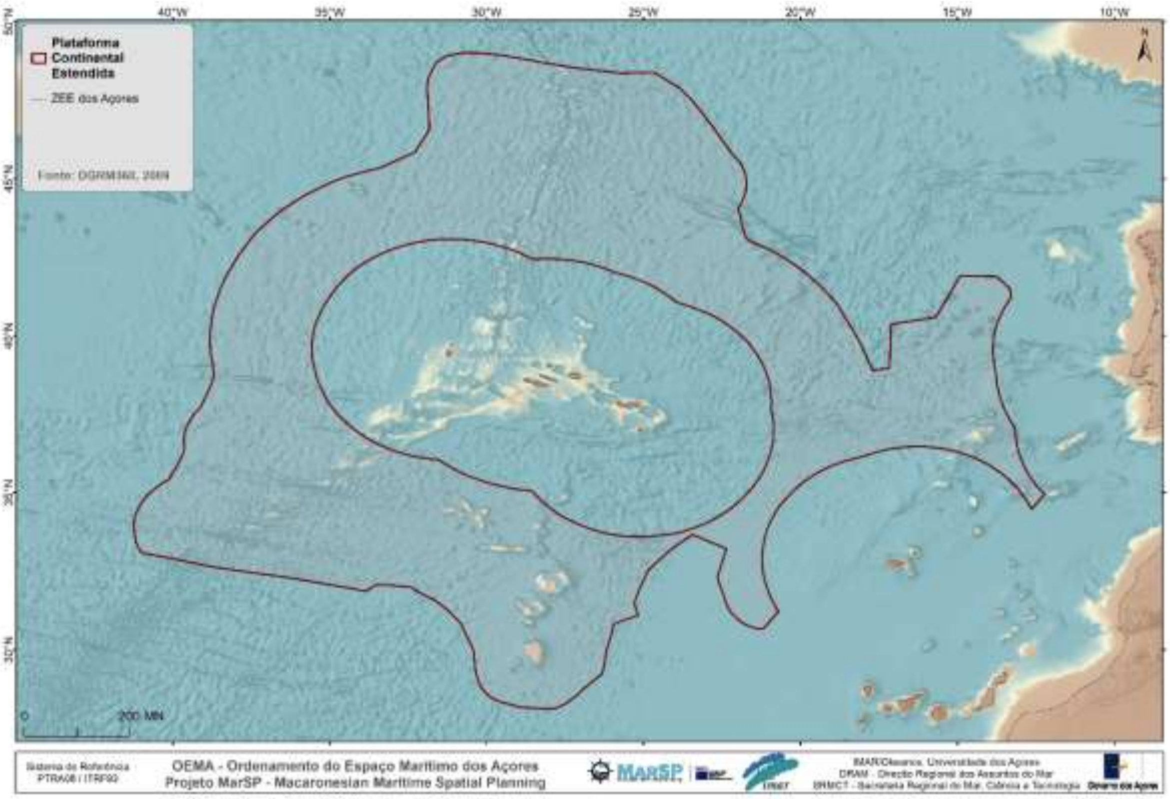
Shapefile: Polygon (1: 1 000 000)

Year: 2009

Keywords: Azores, EEZ, extended shelf, ocean, seafloor

Summary: This layer provides geographic information related to the extended shelf in the Azores Islands, in the North Atlantic Ocean. On this layer, the extended shelf is represented without the area included inside the 200nm of the Exclusive Economic Zone.

Extended Azorean Continental Shelf



Description: Under the United Nations Convention of the Law of the Sea (UNCLOS), the continental shelf is that part of the seabed over which a coastal State exercises sovereign rights with regard to the exploration and exploitation of natural resources including oil and gas deposits as well as other minerals and biological resources of the seabed. The legal continental shelf extends out to a distance of 200 nautical miles from its coast, or further if the shelf naturally extends beyond that limit. The purpose of this layer is to provide information to make a sustainable management of the marine resources in the Azorean sea.

The term “Continental Shelf” includes two distinct concepts: the geological concept and the legal concept. Although both concepts are related to a large extent, the fact is in practice they indicate very different realities, particularly in the Portuguese case.

The continental geological platform concerns the portion of the bed and subsoil of submarine areas which, starting at the coastline, extend with a gentle slope up to a mean depth somewhere between 200 and 300 meters in the transition of the continental slope.

The continental shelf legal concept has been expressed on n.º 1 of Article 76 of the Convention (UNCLOS), which states that the continental shelf of a coastal state "comprises the bed and subsoil of submarine areas which extend beyond its territorial sea over the whole natural extension of their terrestrial territory to the outer edge of the continental margin or up to 200 nautical miles from the baselines from which the territorial sea width is measured, in cases where the outer edge of the continental margin does not reach that distance".

However, and according to n.º 4 of Article 76 of the Convention, the coastal State may establish the outer limit of its continental shelf beyond 200 nautical miles in accordance with scientific criteria. In 2009, Portugal submitted to the Commission on the Limits of the Continental Shelf (CLCS) the demarcation of its continental shelf outer limits beyond 200 nautical miles. The outer continental shelf was submitted considering 3 regions: eastern region - comprising the extension of the platform relating to Madeira archipelago and the mainland; the western region - comprising the extension relating to Azores archipelago; and the Bank of Galicia region, which is an area of common interest to Portugal and Spain, still not divided by bilateral agreement.

The coastal State exercises sovereign rights over the continental shelf for the purpose of exploring and exploiting its natural resources, which are exclusive in the sense that, if the coastal State does not exploit the continental shelf or doesn't take advantage of its natural resources, no one can undertake these activities without its express consent.

Credits: Direção-Geral de Recursos Naturais, Segurança e Serviços Marítimos (DGRM360º); IMAR/Okeanos. University of the Azores.

Use Limitations: "Data is available under the terms of the IMAR Centre (Institute of Marine Research of University of the Azores) data policy".

Extent:

West -41.245436 East -12.209460

North 49.008938 South 28.108523

Citation Contacts:
ORGANIZATION'S NAME DGRM360º
URL:
https://www.dgrm.mm.gov.pt/en/web/guest/am-ec-zonas-maritimas-sob-jurisdicao-ou-soberania-nacional

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CONTACT'S ROLE principal investigator
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Spatial Reference:

* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details

Projected coordinate system
Well-known identifier 3395
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 149134210.44795552
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6.7. FAO Statistical Areas in the Azores

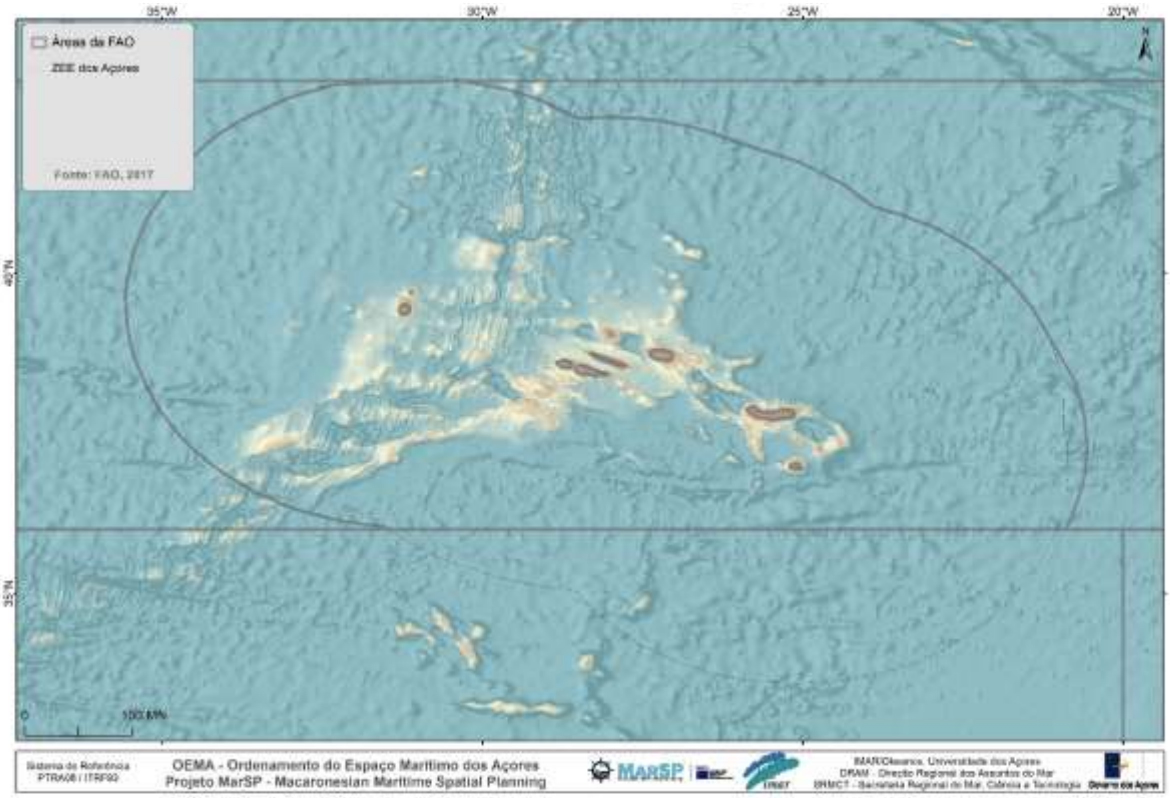
Shapefile: Polygon (1: 1 000 000)

Year: 2017

Keywords: FAO, fishery, fisheries, fishing areas, ocean management, resource management

Summary: This resource provides geographic information in order to make an effective comparison of data, and improves the possibilities of cooperation in statistical matter in general. The rationale of the FAO Major Fishing Areas has been that the areas should, as far as possible, coincide with the areas of competence of other fishery commissions when existing.

FAO Statistical Areas in the Azores



Description: FAO Major Fishing Areas for Statistical Purposes are arbitrary areas, the boundaries of which were determined in consultation with international fishery agencies on various considerations, including (I) the boundary of natural regions and the natural divisions of oceans and seas; (II) the boundaries of adjacent statistical fisheries bodies already established in inter-governmental conventions and treaties; (III) existing national practices; (IV) national boundaries; (V) the longitude and latitude grid system; (VI) the distribution of the aquatic fauna; and (VII) the distribution of the resources and the environmental conditions within an area. URL: http://www.fao.org/fishery/area/Area27/en

Credits: Food & Agriculture Organization of the United Nations. "Fisheries and Aquaculture Department. Statistics and Information"

Use Limitations: The use limitation of this layer is according to the FAO regulation.

Extent:

West -179.999989 East 179.999989

North 89.000000 South -87.983436

Citation Contacts:
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CONTACT'S ROLE GIS Consultant
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Spatial Reference:
* TYPE Projected
* Geographic coordinate reference GCS_WGS_1984
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details
Projected coordinate system
Well-known identifier 3395
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Latest well-known identifier 3395
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6.8. OSPAR Marine Protected Areas

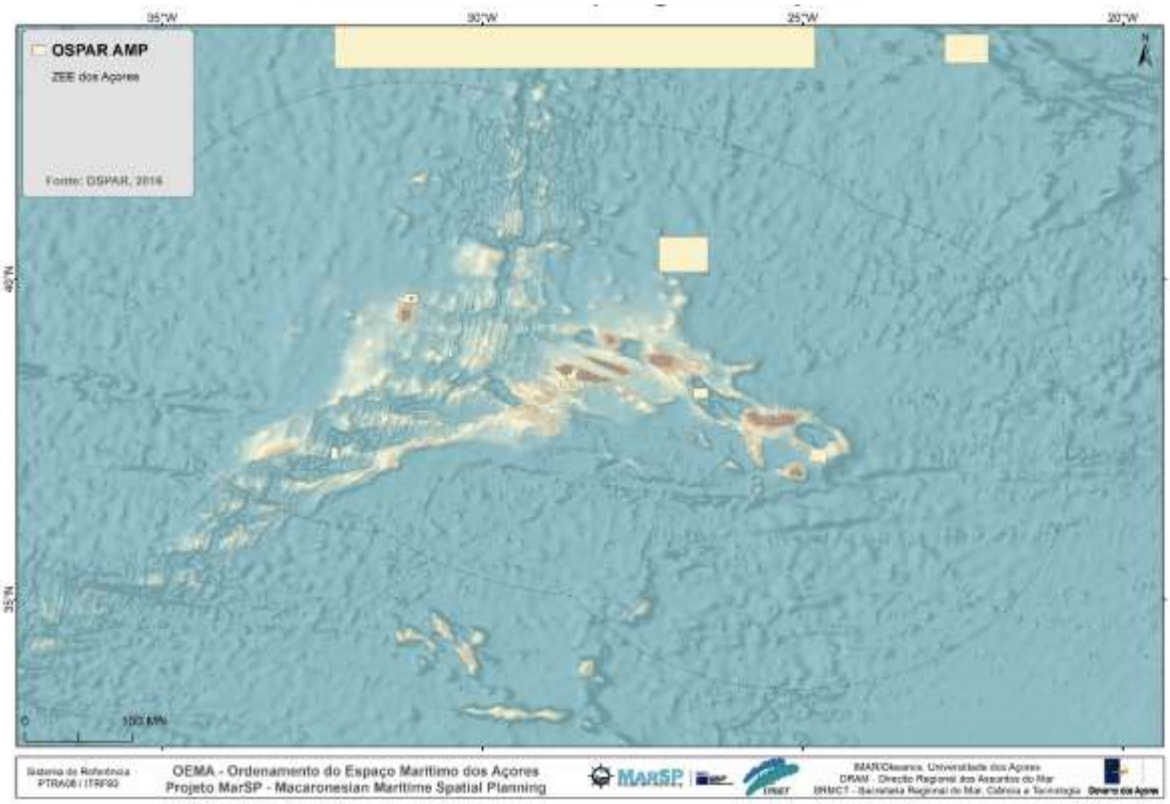
Shapefile: Polygon (1: 1 000 000)

Year: 2016

Keywords: Protected areas, MPA, OSPAR

Summary: OSPAR Network of Marine Protected Areas Within OSPAR, MPAs are understood as areas for which protective, conservation, restorative or precautionary measures have been instituted for the purpose of protecting and conserving species, habitats, ecosystems or ecological processes of the marine environment.

OSPAR Marine Protected Areas in the Azores



Description: OSPAR Network of Marine Protected Areas Within OSPAR, MPAs are understood as areas for which protective, conservation, restorative or precautionary measures have been instituted for the purpose of protecting and conserving species, habitats, ecosystems or ecological processes of the marine environment.

http://www.ospar.org/content/content.asp?menu=00700302210000_000000_000000

Credits: JNCC Data Services

Use Limitations: " Terms and conditions If you have any queries, please contact JNCC Data Services, Joint Nature Conservation Committee, Monkstone House, Peterborough PE1 1JY, dave.chambers@jncc.gov.uk or telephone +44 (0)1733 - 866 882. 1. Licence We grant you a non-exclusive non-transferable licence to use, copy and adapt the data which is derived from Ordnance Survey data ('Data') in accordance with the terms of this licence agreement. You may only use the Data for your own internal business purposes meaning for any purpose relating to a statutory, governmental or regulatory function and not for financial profit or gain. You may only use the Data for your own internal business purposes meaning for any purpose relating to a statutory, governmental or regulatory function and not for financial profit or gain. This licence is applicable until 31 March 2009, after which it will terminate. 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Promises you acknowledge that the data has not been prepared to meet your individual requirements and therefore it is provided to you on an 'as is' basis. it is your responsibility to ensure that the data is fit for your intended use. to the fullest extent permitted by law we exclude any conditions or terms that may be implied by law. we shall not in any event be liable for any indirect, special, consequential, or incidental losses or for loss of data, loss of profits, loss of or interruption to business whether arising in tort (including negligence) contract or otherwise. we do not attempt to exclude any liability that cannot be excluded. excepting the above, our total and aggregate liability to you in contract, tort (including negligence) or otherwise will not at any time exceed an amount equal to any purchase price or licence fee paid to jncc. 4. Terminate We may terminate this licence at any time if any of the following events arises: You breach any of the terms of this licence; You become insolvent or bankrupt or cease to do business. In the event of termination of this licence, you shall cease to use the Data and if we request, you shall immediately return the Data or destroy them and provide to us an affidavit or sworn statement from one of your executives confirming the same. 5. Law This will be governed by and construed in accordance with English law and both parties accept the exclusive jurisdiction of the English courts. If any part of this licence is held to be invalid, unenforceable, or illegal, we both agree that the remainder of the licence will stand.".

Extent:

West	-34.461180	East	-22.101180
North	44.860668	South	36.217428

Citation Contacts:
ORGANIZATION'S NAME Tim Packeiser
ORGANIZATION'S NAME JNCC Data Services
E-MAIL ADDRESS: tim.packeiser@bfn-vilm.de

Point of Contact:
INDIVIDUAL'S NAME Luis Rodrigues
ORGANIZATION'S NAME IMAR/Okeanos. University of the Azores
CONTACT'S POSITION Geospatial Data Scientist
E-MAIL ADDRESS lmcrod@gmail.com

Spatial Reference:

* TYPE Projected
* PROJECTION WGS_1984_World_Mercator
* Coordinate reference details

Projected coordinate system
Well-known identifier 3395
X ORIGIN -20037700
Y ORIGIN -30198300
XY SCALE 10000
Z ORIGIN -100000
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XY TOLERANCE 0.001
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Latest well-known identifier 3395
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PROJCS["WGS_1984_World_Mercator",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137.0,298.257223563]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Mercator"],PARAMETER["False_Easting",0.0],PARAMETER["False_Northing",0.0],PARAMETER["Central_Meridian",0.0],PARAMETER["Standard_Parallel_1",0.0],UNIT["Meter",1.0],AUTHORITY["EPSG",3395]]

Final note

This report notes the importance of systematization and revision of available spatial information for the better understanding of the Azorean Seas. It is only through the use of the best available information that it is possible to acquire of a deeper knowledge.

The availability of this spatial dataset crucially contributes for the improvement of the capacity of Maritime Spatial Planning of the Azores. These spatial datasets allow for the joint manipulation of several topics, integrated into a single answer in the form of a map, for the Maritime Spatial Planning of the Azores.

Throughout these spatial datasets, sorted into six different pre-established categories, the multidisciplinary nature of the approach on Azorean Sea affairs is strengthened, as it is inherent to the Geographical Information Systems for the spatial planning.

Thanks to the characteristics of this compilation, in particular the fact that the coordinate system is identified in all spatial datasets, all of the topics can be interconnected with each other.

Several data sources were identified and used and diverse data formats constitute this spatial dataset. A huge effort of feature compatibilization of spatial data was done in order to give coherence to this data compilation exercise. Nevertheless, thanks to this effort of data acquisition, the updating process is made much easier.

Finally, in the deliverable “D.3.5. Spatial distribution maps of species, habitats and impacts” several graphical outputs were developed and made available for the visualization of illustrative thematic maps of the spatial datasets from all proposed topics. Therefore, conditions for increasing the communication capacity of data about the Azorean Seas have been created.

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Multidisciplinary characterization of the new Luso hydrothermal vent field (Mid-Atlantic Ridge, Azores)

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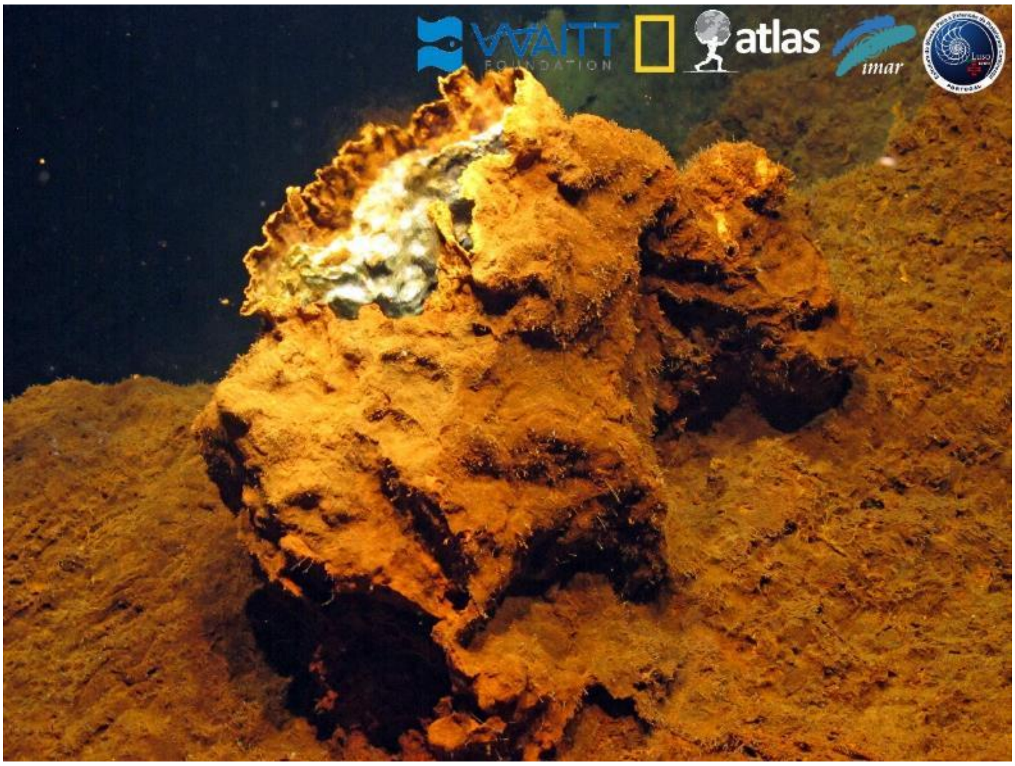
Executive Summary



October 2019

Executive summary

In order to comply with the provisions of the cooperation protocol between IMAR and the Blue Ocean Foundation, namely in which concerns with the Clause Six, (b) *submission to the Blue Ocean Foundation of Report on the Luso hydrothermal source and including recommendations for the protection of all hydrothermal vents in the Azores EEZ*, we have prepared the attached report that is briefly summarized here.

The discovery

A new hydrothermal vent field was discovered on the slopes of Gigante, a seamount on the Mid-Atlantic Ridge in the seas of the Azores. This system differs considerably from other known hydrothermal fields along the MAR in terms of fluid chemistry with dominance of hydrogen and iron, and low temperature. These elements support diverse chemoautotrophic microbial communities and benthic fauna, with several putative new species to science. The great majority of the bacteria identified in this study were thermophilic, capable of coping with thermal and osmotic stress, representing potential "microbial cell factories", important in industrial technology. The diffuse fluid emission released by this type of hydrothermal system may represent an important but overlooked source of iron to the oceans, an essential element to primary productivity, thus playing a potentially important role as "fertilizers" of oligotrophic oceanic systems as those in the Azores.

Management implications and recommendations

Active hydrothermal vents ecosystems host rare, endemic, and fragile species adapted to life in extreme conditions. Because of its ecological and biological importance but also because of the growing threats posed to hydrothermal vents, there have been global growing efforts to protect them. The Azores Region of Portugal pioneered some of these efforts, and the creation of the Marine Park of the Azores in 2007 was one of the first examples of Marine Protected Areas that included hydrothermal vents. The hydrothermal vents Menez Gwen and Lucky Strike were included in the Azores Marine Park in 2011 as Nature Reserves and are protected against bottom contact fishing, deep-sea mining, dumping and other activities that may cause harm to the marine environment (DLR n.º 28/2011/A). The Rainbow vent field was declared as a Nature Reserves located in the continental shelf behind 200nm claimed by Portugal, but it lacks effective protection measures (DLR n.º 28/2011/A). The Menez Hom, Famous, Saldanha, and Amar were included in the 2016 revision of the Azores Marine Park as part of the PMA13 MPA, but also lack effective protection measures (DLR n.º 13/2016/A). In fact, deep-sea mining exploration activities are not prohibited in PMA13, but they require special permits as it would be necessary for any other area. It would be desirable that existing regulations for Menez Gwen and Lucky Strike would also be applied to the Menez Hom, Famous, Saldanha, and Amar. Additionally, deep-sea mining exploration and exploitation should be fully prohibited inside the Azores Marine Park, but mainly in the PMA 13 (which includes PMA2, 3 and 4) in PMA 12 and in PMA 11 (which included PMA 1).

The new Luso hydrothermal vent field may not host important mineral resources, but it's a unique field in the Azores characterized by low temperature, high hydrogen, and iron-rich fluids supporting unique (and probably new and endemic) biological communities. It is likely that the area of influence of the hydrothermal vent field is shaping the biological communities living in the background which is characterized by abundant balonomorph barnacles and diverse coral gardens composed by the bubble gum coral *Paragorgia* spp. and the soft coral *Anthomastus* c.f. *agaricus*. Because of these characteristics, the Luso hydrothermal vent field should be declared an MPA, classified as a Nature Reserve, and included in the Azores Marine Park. In fact, following the discovery of the Luso vent field in the Gigante seamount, scientists and other stakeholders called for full protection of the new vent field; the only one of its kind. The Regional Government of the Azores declared the Luso hydrothermal vent field as a Marine Protected Area fully protected from fisheries in September 2019 (Portaria n.º 68/2019). However, the regulation does not mention other activities rather than fisheries, and therefore deep-sea mining exploration and scientific research were not subject to specific rules or prohibitions.

A long-term vision

This new exciting discovery has the particularity of being located in an important fishing ground close to the shores of the Azores, highlighting once again how little we know about the deep-sea even when the deep-sea is our backyard. At a time when the UN is developing a new international agreement on the conservation and sustainable use of biodiversity in areas beyond national jurisdiction (BBNJ), individual countries must develop science-based management strategies for deep-sea exploration on their own waters as a basis for conservation and sustainable management of the deep-sea in national jurisdictions. Such strategies should translate in real efforts to develop consistent fieldwork activities for mapping vulnerable marine ecosystems and defining baseline conditions. The European Union, and nations like Portugal in particular, are taking great strides to develop trans-Atlantic collaborations to map the deep-sea. It would be a costly mistake to neglect what needs to be discovered and protected in the deep-ocean waters close to our shores, much of which remains to be discovered. Therefore, we need to create a long-term strategy for increasing scientific knowledge of the Azores deep sea, namely by continuing ongoing efforts to map and identify areas in the deep sea of the Azores that fit the FAO definition of VME. However, this will also be possible if the Azores are endowed with adequate technological means for the implementation of the long-term strategy for increasing scientific knowledge to support sustainable management and conservation.

Summary of recommendations

1. ***Menez Hom, Famous,*** **Saldanha, and Amar** vent fields should also be protected against bottom contact fishing, deep-sea mining, dumping and other activities that may cause harm to the marine environment; similarly to the Menez Gwen and Lucky Strike the hydrothermal vents;
2. The new ***Luso hydrothermal*** should be protected against extractive activities other than fisheries (e.g. potential deep-sea mining), dumping and other activities that may cause harm to the marine environment; although this vent has already been protected against all types of fishing gears (Portaria n.º 68/2019);
3. Specific management regulations for the ***Rainbow*** hydrothermal vent MPA, located in the extended continental shelf claim by Portugal, should be agreed and fully implemented;
4. Deep-sea mining exploration and exploitation should be fully prohibited inside the ***Azores Marine Park***, but mainly in the PMA13 (which includes PMA2, 3 and 4) in PMA12 and in PMA11 (which included PMA 1);
5. ***Adopted and fund a long-term strategy*** should be to advance the understanding of the natural diversity, ecosystem structure, function, connectivity and resilience of deep-sea communities in a changing planet while informing the environmentally sustainable use of natural resources;
6. Endow the Azores region with ***adequate human and technological resources*** for the implementation of the above long-term strategy.

Multidisciplinary characterization of the new Luso hydrothermal vent field (Mid-Atlantic Ridge, Azores)

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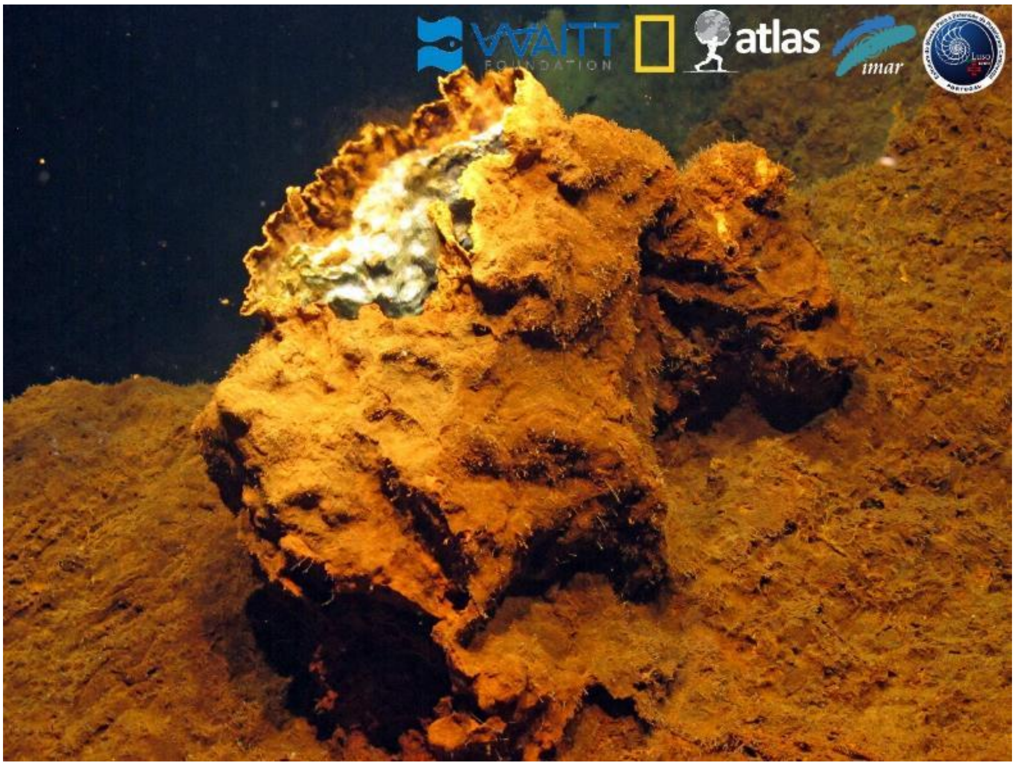

October, 2019

Introduction

Several active deep-water hydrothermal vent fields have been discovered in the north portion of the slow-spreading Mid Atlantic Ridge (MAR). Five of them are located in the Portuguese EEZ around the Azores (Beaulieu et al., 2013), relatively close to each other and to the Azores islands. These are the Menez-Gwen (at 850m depth) including Bubbylon, Lucky Strike (1700m) including Ewan, Menez Hom (1800m), Saldanha (2200m), and Rainbow (2400m; in the Extended Continental Shelf). Recently, the Moytirra hydrothermal vent area was discovered north of the Azores (2900m) at about 45.5°N (Wheeler et al., 2013). However, the detection of several hydrothermal plumes signal on the northern Mid-Atlantic Ridge may indicate that more active fields may occur in the region (Hydes et al., 1986; German et al, 1996; Chin et al., 1998; Aballea et al., 1998; Beaulieu et al., 2015), as recently demonstrated for fast- and intermediate-rate spreading ridges (Baker et al., 2016).

Here, we describe a new hydrothermal vent field discovered on June 16th 2018 on the slopes of Gigante (Figure 1), a seamount located on the MAR, half-way between Pico and Kurchatov fracture zones. The Luso hydrothermal vent field was uncovered at 570 m depth during the Blue Azores 2018 Expedition with the ROV LUSO onboard NRP Gago Coutinho. Following this discovery, and taking advantage of an ongoing collaboration between IMAR, Okeanos-UAz and Nadine Le Bris from the Sorbonne Université, the Luso vent field was revisited on August 4th 2018 with the ROV VICTOR6000 onboard the RV L'Atalante to perform additional observations and sampling for a multidisciplinary characterization of the discovered vent field.

Geological setting

Gigante is ridge-like seamount (~10 x 6 km) that rises 800 m from the seafloor to water depths of ~150 m. It follows the main trend of the Azores volcanic emplacement direction (~110-120º) and is crossed by lineaments parallel to the Mid-Atlantic Ridge (MAR) (Lourenço et al., 1998). Moreover, it is located in the southern edge of the diffuse boundary between the Nubia and Eurasia lithospheric plates, whose intersection with the MAR defines the locus of the Azores triple junction (Miranda & Luis, 2008; Marques et al., 2013). The combination of Azores magmatic processes with their contiguity to the MAR makes the Gigante seamount a place of interest to assess on-going volcanic-tectonic and hydrothermal processes, in the context of a large-scale plume-ridge interaction, affecting the Azores Platform between Hayes and Maxwell fracture zones.

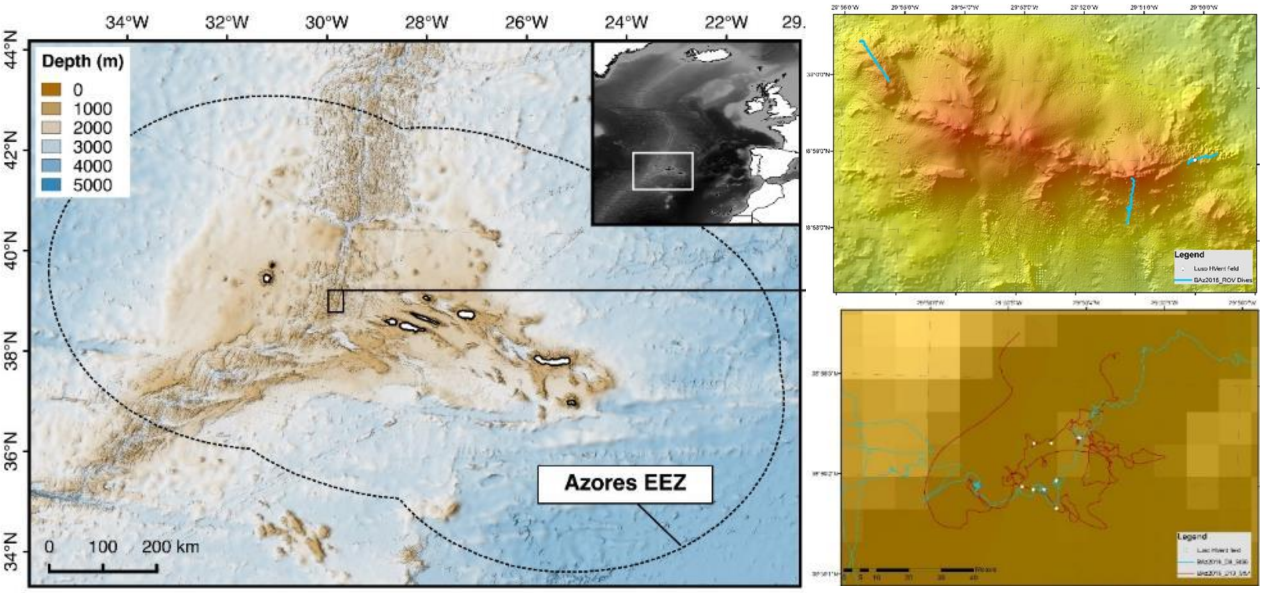

Figure 1. *Map of the location of the large Gigante seamount complex (left) and the Gigante seamount (right) with the "Luso" hydrothermal vent field (white dot in the top right panel). Known chimney-like structures are also shown (white dots in bottom right panel). Blue and red lines show ROV dives conducted during the Blue Azores Expedition 2018.*

Hydrothermal vent field

Luso hydrothermal vent field occupies an area of about 400 m^2 and is composed of at least 26 chimney-like structures of different sizes; with orifices up to about 30 cm in diameter (Figure 2). Active and inactive vent chimneys are distributed preferentially along the ENE-WSW fractures.

Mineralogy and geochemistry: Chimneys were composed of loose and fragile material, displaying a concentric composition reflected in different colours and textures. In general, three compositional zones could be recognized: I) the innermost zone, which is in contact with the hydrothermal fluid, composed of white, loose and low-density precipitates, with rare green clays, with a mineralogical composition characterized by a dominance of amorphous Si (Opal A); II) the middle zone shows brownish to yellowish precipitates, intermixed with olive-green clays scattered locally, with a mineralogical composition characterized by an intermixed clay composition with amorphous Si and oxyhydroxides; and III) the outermost zone is composed by brownish ochre material, dominated by Fe-Mn oxyhydroxides (Figure 2). Inactive chimneys do not present a clear zonation and are dominated by a darker material, showing enrichment in Fe-oxyhydroxides crosscut by fine and dark glassy veinlets with a deep purple tint (identified as amorphous silica) and an unclear zone I, well-defined in the active chimneys.

***Figure 2**. Examples of chimney-like structures in the "LUSO" hydrothermal vent field. Credits: © ROV Luso/EMEPC / 2018 Oceano Azul Expedition.*

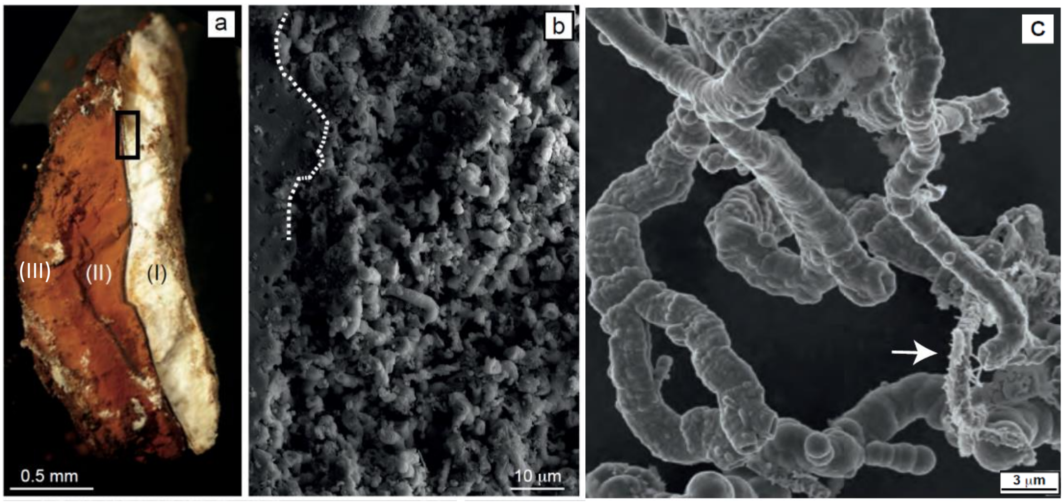

Figure 3. *(a) Photomicrograph of a fragment taken from an active Luso chimney showing zones I (core), II (middle zone) delimited by a fine, compact glassy layer and III (outermost zone) composed by Fe-Mn oxyhydroxides (b) scanning electron microscopy (SEM) images of a detail of zone I composed by µm-tick filamentous aggregates limited to the left by the veinlet (dashed line shows veinlet limit); (c) filamentous hollow globular aggregates with branching, embraced by a braid-like stalk (white arrow).*

Hydrothermal vent fluid composition: Hydrothermal fluids were transparent but well noticeable from a distance. They were moderately warm reaching a stable maximum temperature of 62°C when measured *ca.* 10 cm inside the outer rim of the main chimney conduit. Fluids were moderately acidic (pH 5.6-5.7), iron-rich (from 226.3 to 336.7 µM total HNO3-leachable iron), CO_2 rich, hydrogen-rich (up to 357 µM), with moderate methane contents (up to 4.9), but contain no sulphides (Table 1). This system thus differs considerably from other hydrothermal fields along the MAR, characterized by fluids of high temperature, high concentrations of methane, sulphur and metals, supporting high biomass of specialized chemosynthetic fauna (Van Dover, 2000). The geological and physical-chemical nature (low temperature, high CO_2) of this vent system resembles the low-temperature hydrothermal vents (Pele's vents) at Loihi Seamount in Hawaii (Karl et al., 1988), and elsewhere in the Pacific (Alt et al., 1988; Kennedy et al., 2003; Edwards et al., 2004) dominated by extensive deposits of Fe oxides of microbial origin.

Table 1. *Hydrothermal vent fluid chemistry of different vent chimneys within the Luso hydrothermal vent field.*

#	Site	pH	CH_4 (µmol/l)	H_2 (µmol/l)	NH_4^+ (µmol/l)	NO_3^- (µmol/l)	HCl-dFe (µmol/l)	HNO3-dFe (µmol/l)	HNO3-TFe (µmol/l)	HCl-dFe/Tfe %
1	Large chimney	5.55	4.89	19.29	48.1	0	317.92	332.8	336.71	94.40%
2	Large chimney	5.55	3.79	122.21	53.59	0	335.15	337.49	339.84	98.60%
3	Small chimney	5.6	2.3	3.67	85.99	33.4	204.38	205.94	242.75	84.20%
4	Small chimney	5.68	0.31	357.09	225.82	0	162.87	167.57	226.3	72.00%

#	Site	HNO3-dFe/Tfe %	Na^+ (mmol/l)	Mg^{2+} (mmol/l)	Ca^{2+} (mmol/l)	Cl^- (mmol/l)	SO_4^{2-} (mmol/l)	Br^- (mmol/l)	K^+ (mmol/l)	Li^{2+} (mmol/l)
1	Large chimney	98.80%	310.81	24.9	18.15	601.05	22.38	0.41	7.11	0.0295
2	Large chimney	99.30%	482.98	39.77	24.29	1119.63	25.37	0.62	11.22	0.0405
3	Small chimney	84.80%	171.21	14.35	8.34	255.24	20	0.22	3.52	0.0107
4	Small chimney	74.00%	476.04	46.22	17.06	1038.8	32.43	0.62	10.56	0.0327

Biological communities

Microbiology: The microbial communities from two active chimneys were highly diverse, with a stronger presence of *Bacteria* in relation to *Archaea* (Table 2, Figure 4). Microbial taxa involved in the cycle of hydrogen, iron and sulphur dominated these communities (Figures 5). These were mainly represented by Operational Taxonomic Units (OTU) related with:

- *Aquificae* genus *Persephonella* - thermophilic hydrogen oxidizing lithotrophs (Takai & Nakagawa, 2014);
- the *Nitrospirae* genus *Thermodesulfovibrio* - thermophilic sulphate reducers capable of oxidizing hydrogen, and reducing sulphate into sulphide (Sonne-Hansen et al., 1999); and
- *Zetaproteobacteria* genus *Mariprofundus* - a microaerophilic iron-dependent chemolithotrophic bacteria.

These marine iron-oxidizers produce unique filamentous stalk-like structures, consisting primarily of iron-oxyhydroxides (Chan *et al.*, 2010), and are considered to play a significant role in the generation of massive iron-rich mats on the seafloor (Emerson & Moyer, 2002).

Table 2. *Diversity and richness indexes for bacterial and archaeal communities. Samples refer to inner large chimney L18R1, outer small chimney L18R2 and to inner small chimney L18R2. Biodiversity estimates are presented as subsamples average number of Operational Taxonomic Units (OTUs), Chao1 richness estimates, Shannon-Weiner, Simpson's and Evenness diversity indices estimates ± standard deviation (Hughes et al., 2001; Kim et al., 2017).*

	L18R1	**L18R2**	**L18R2**
Bacteria			
OTU	2289 ± 1126	1900 ± 555	2563 ± 1217
Chao1	2505 ± 1111	2270 ± 529	2931 ± 1258
Evenness	0.57 ± 0.03	0.60 ± 0.04	0.60 ± 0.08
Shannon	6.25 ± 0.72	6.47 ± 0.73	6.74 ± 1.33
Simpson	0.93 ± 0.03	0.91 ± 0.06	0.89 ± 0.09
		Archaea	
OTU	990 ± 138	589 ± 85	986 ± 80
Chao1	1134 ± 139	685 ± 131	1084 ± 128
Evenness	0.56 ± 0.02	0.48 ± 0.03	0.55 ± 0.02
Shannon	5.48 ± 0.28	4.44 ± 0.42	5.44 ± 0.21
Simpson	0.93 ± 0.01	0.91 ± 0.01	0.92 ± 0.01

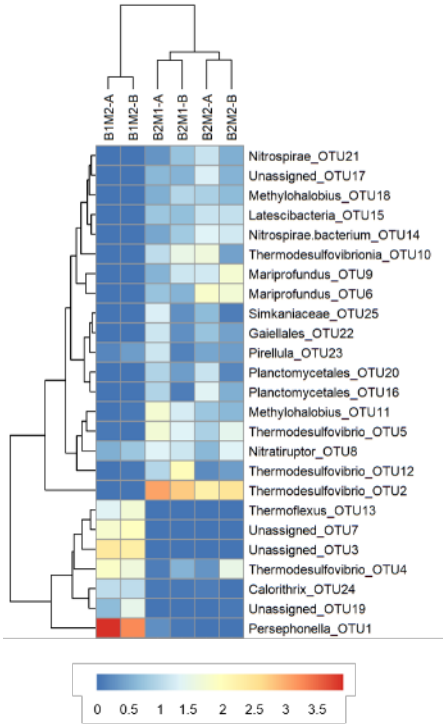

Figure 4. - Heatmap and double hierarchical cluster showing the operational taxonomic units (OTUs) relative abundance across all chimney samples from the Luso vent field. Only the 25 more abundant bacterial OTU were included. OTU cluster was based on a Euclidean distance. Sample cluster was based on the Bray-Curtis dissimilarity index performed on the normalized by total and log(x+1)-transformed OTU data matrix. The red and blue color variation indicates the relative abundance of reads/OTU, being red for a high number and blue for a reduced number of reads. Sample codes are B1M2 large inner chimney, B2M1 outer small chimney and B2M2 inner small chimney.

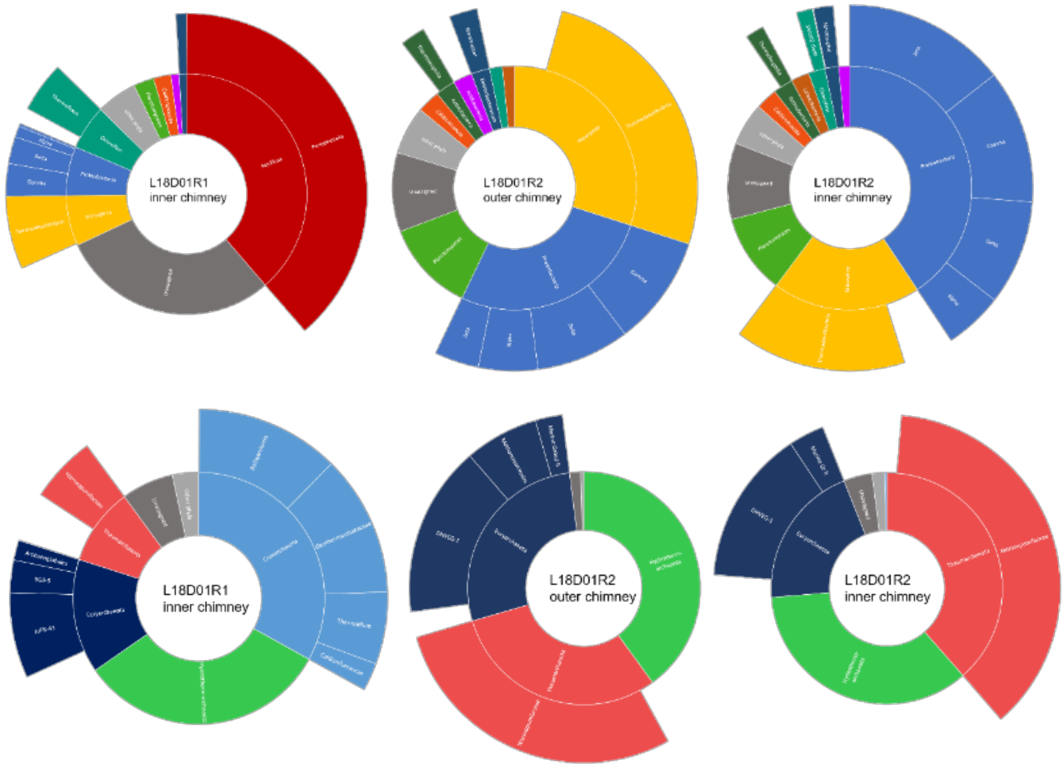

Figure 5. Taxonomic distribution and relative abundance of bacterial (top) and archaeal taxa in hydrothermal bulk wall samples retrieved from the Luso vent field (L18R1 inner large chimney, L18R2 small outer chimney and L18R2 inner small chimney). Sunburst charts show the Phylum-Class/Genus distribution for taxonomically assigned sequences that occurred more than 1% of total reads in each site. Sequences that did cluster into OTUs with no resemblance to any known bacterial phylum were grouped into "Unassigned Phyla". "Alpha", "Delta" "Gamma" and "Zeta" corresponds to the related Proteobacteria classes. Sequences that did cluster into OTUs with no resemblance to any known archaeal phylum were grouped into "Unassigned Phyla".

Most archaeal OTUs clustered with uncultured clone groups, such the *Hydrothermarchaeota* (*MBGE*), *Deep-Sea Hydrothermal Vent Group 1* (*DHVEG-1*)*, Marine Group II*, all previously reported in other deep-sea environments. *Hydrothermarchaeota* were described as having the capacity for both sulphate and nitrate reduction (Carr et al., 2019). Together with *Archaeoglobus* representatives and the bacterial *Thermodesulfovibrio,* they are likely contributing to the sulphate reduction potential in Luso microbial ecosystem. Together these results pointed to the presence of phylogroups that corroborate the occurrence of an iron and hydrogen metabolisms at Luso vent, and appear to be the basic drivers of ecosystem productivity at the studied sites.

Macro and megafauna: Biological observations on the vents showed no typical hydrothermal vent macrofaunal, as opposed to other hydrothermal vent fields along the MAR (Van Dover, 2000). However, a total of 28 taxa were identified from the LUSO vent field, corresponding to 8 phyla (Table 3). None of the observed taxa are considered vent specific, being Crustacea the largest group collected, both in terms of the number of organisms and species. For many taxa, the identification of specimens could only be made to Family level, with the number of species potentially increasing after revision by specialized taxonomists.

Table 3. *Fauna recorded at the Luso hydrothermal vent on the Gigante Seamount. Three areas within the vent field were visited: Vent area 1 - primary venting area dominated by large vent chimneys; Vent area 2 - secondary venting area dominated by small vent chimneys; vent area 3 - inactive vent chimneys; Balsatic rocks outside vent field. *Fauna recorded through ROV video observations.*

Taxa	**Vent area 1**	**Vent area 2**	**Vent area 3**	**Vent field Background**
FORAMINIFERA				X
PORIFERA				
Demospongiae indet. 1				X
Demospongiae indet. 2				X
Demospongiae indet. 3				X
Encrusting sponges (c.f. Hymedesmidae)*		X	X	X
Poecillastra compressa (Bowerbank, 1866)*				X
Polymastia sp.*				X
Farrea occa Bowerbank, 1862*			X	X
Regadrella phoenix Schmidt, 1880*			X	X
CNIDARIA:Hexacorallia				
Scleractinia				
Caryophyllia (Caryophyllia) cyathus (Ellis & Solander, 1786)				X
Stenocyathus vermiformis (Pourtalès, 1868)				X
Antipatharia				
Parantipathes c.f. *hirondelle* Molodtsova, 2006*				X
Stichopathes c.f. *gravieri* Molodtsova, 2006*				X
Zoantharia				
Parazoanthus aliceae Carreiro-Silva et al 2017		X		
CNIDARIA: Octocorallia				
Acanthogorgia cf. *armata* Verrill, 1878*				X
Paragorgia johnsoni Gray, 1862*		X		X
Paragorgia arborea(Linnaeus, 1758)*			X	X
Pleurocorallium johnsoni (Gray, 1860)*			X	X
Nidaliidae indet.*				X
Narella bellissima (Kükenthal, 1915)*				X
Leptosammia Formosa				X
Swiftia rosea (Grieg, 1887)				
Anthomastus c.f. agaricus Studer, 1890*			X	X
CNIDARIA: Hydrozoa				

Taxa	Vent area 1	Vent area 2	Vent area 3	Vent field Background
Ectopleura larynx (Ellis & Solander, 1786)	X	X		X
Sertularia sp 1		X		
Sertularia sp 2				
Haleciidae indet		X		X
BRYOZOA				
c.f. *Sertella* sp.				X
c.f. *Crisia* sp.				X
NEMERTEA				
ANNELIDA: Polychaeta				
c.f. *Neanthes kerguelensis* (McIntosh, 1885)		X	X	
Euniceidae indet.		X		
SIPUNCULIDA				
c.f. *Golfingia vulgaris* (Blainville, 1827)				X
Golfingiidae indet.				X
MOLLUSCA: Gaspropoda				
Calliostoma lithocolletum Dautzenberg, 1925	X			
Catapaguroides microps A. Milne-Edwards and Bouvier, 1892		X		
Alvania sp.		X		
MOLLUSCA:Bivalvia				
c.f. *Acanthocardia echinata* (Linnaeus, 1758)				X
CRUSTACEA: Amphipoda				
c.f. *Nopotoma* (Cerapus or Paracerapus)	X	X		
c.f. *Gammaropsis* sp.				X
Liropus sp 1	X	X		
Liropus sp2	X	X		
Pseudoprotella sp	X	X		
CRUSTACEA: Copepoda				
Harpacoidea indet.	X	X		
CRUSTACEA: Cirripedia				
Pachylasma c.f. *giganteum*		X	X	
CRUSTACEA: Decapoda				
Caridae indet.				
Paromola cuvieri (Risso, 1816)*		X	X	
Bathynectes maravigna (Prestandrea, 1839)*				X
NEMATODA				
Chromadora indet.			X	
ECHINODERMATA:Ophiuroidea				
Ophiactis sp.		X		X
ECHINODERMATA: Asteroidea				
Pentagonaster sp.		X		
ECHINODERMATA: Echinoidea				
Cidaris cidaris (Linnaeus, 1758)				X
Echinus melo Lamarck, 1816				X
CHORDATA				
Helicolenus dactylopterus (Delaroche, 1809)*				X
Conger conger (Linnaeus, 1758)*				X
Gadidae indet.*				X
Lophius sp.*			X	
Pagellus bogaraveo (Brünnich, 1768)			X	
Total number of (morpho)species	7	20	8	27

Dense aggregations of the tubiculous amphipods of the Family Ischyroceridae (c.f. genus *Nopotomus*) dominated the external surfaces of the active and inactive vent chimneys but appeared more abundant in active vent chimneys (Figure 7). This is a putative new species to science, which requires further verification. Amphipods of the Family Capprellidae were commonly observed together with the tubiculous amphipods, and the presence of the gastropod *Calliostoma lithocolletum* was also noted in the large active chimney of the primary venting area. Conspicuous faunal elements in the secondary venting areas dominated by small active chimney area were the large balonomorph barnacle cf. *Pachylasma giganteum* with signs of iron precipitation on its exoskeleton and the zoanthid *Parazoanthus aliceae* (Figure 6). The crustacean *Paromola cuvieri* was also commonly observed in the vicinity of the small active chimneys but were also common outside the vent field. Chimney walls were also densely populated by hydrarians of the genus *Sertularella* and *Lafoe dumosa*. Inactive vent chimneys were characteristically covered by tubiculous amphipods, the hydrarian *Ectopleura larynx* and small recruits of the balanomorph barnacle *P. giganteum*. As the vent field area ends, the abundance of balonomorph barnacles is progressively reduced and diverse coral gardens composed by the gorgonians *Paragorgia aborea*, *P. johnsoni*, *Pleurocorallium johnsoni* and soft coral *Anthomastus* c.f. *agaricus,* among other species, dominate outcrops of pillow basalts (Figure 6).

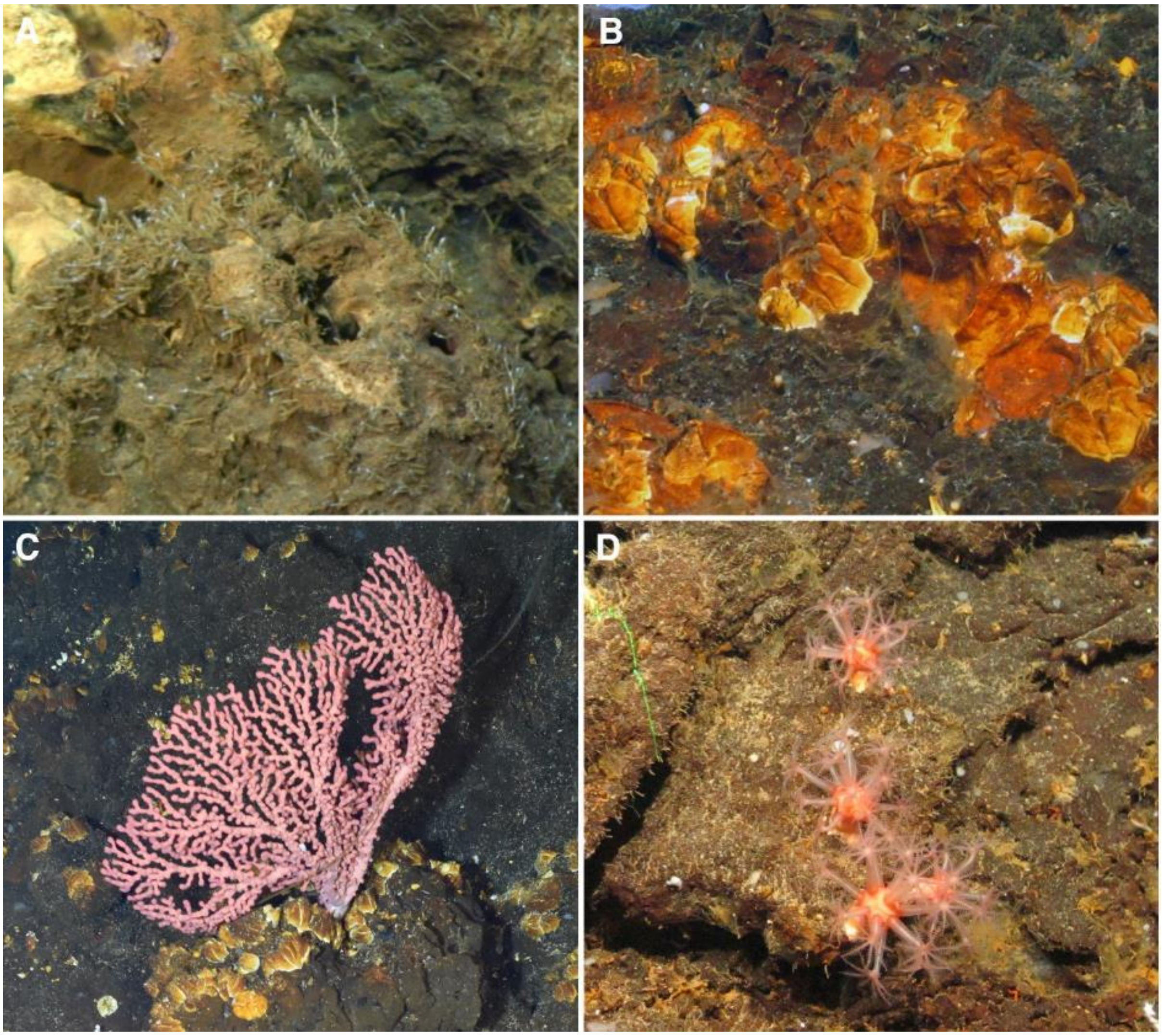

Figure 6. *Examples of the benthic macrofauna found on Luso hydrothermal vent field. a) tubiculous amphipods of the Family Ischyroceridae (cf. genus* Nopotomus*), b) balonomorph barnacle cf.* Pachylasma giganteum *with signs of iron precipitation on its exoskeleton, c)* Paragorgia arborea *and d*) Anthomastus cf. agaricus. *Credits: © ROV Luso/EMEPC / 2018 Oceano Azul Expedition.*

Conclusion

A new hydrothermal vent field was discovered on the slopes of Gigante, a seamount on the Mid-Atlantic Ridge in the seas of the Azores. This system differs considerably from other known hydrothermal fields along the MAR in terms of fluid chemistry with dominance of hydrogen and iron, and low temperature. These elements support diverse chemoautotrophic microbial communities and benthic fauna, with several putative new species to science. The great majority of the bacteria identified in this study were thermophilic, capable of coping with thermal and osmotic stress, representing potential "microbial cell factories", important in industrial technology. The diffuse fluid emission released by this type of hydrothermal system may represent an important but overlooked source of iron to the oceans, an essential element to primary productivity, thus playing a potentially important role as "fertilizers" of oligotrophic oceanic systems as those in the Azores.

This new exciting discovery has the particularity of being located in an important fishing ground close to the shores of the Azores, highlighting once again how little we know about the deep-sea even when the deep-sea is our backyard. At a time when the UN is developing a new international agreement on the conservation and sustainable use of biodiversity in areas beyond national jurisdiction (BBNJ), individual countries must develop science-based management strategies for deep-sea exploration on their own waters as a basis for conservation and sustainable management of the deep-sea in national jurisdictions. Such strategies should translate in real efforts to develop consistent fieldwork activities for mapping vulnerable marine ecosystems and defining baseline conditions. The European Union, and nations like Portugal in particular, are taking great strides to develop trans-Atlantic collaborations to map the deep-sea. It would be a costly mistake to neglect what needs to be discovered and protected in the deep-ocean waters close to our shores, much of which remains to be discovered. Therefore, we need to create a long-term strategy for increasing scientific knowledge of the Azores deep sea, namely by continuing ongoing efforts to map and identify areas in the deep sea of the Azores that fit the FAO definition of VME. However, this will also be possible if the Azores are endowed with adequate technological means for the implementation of the long-term strategy for increasing scientific knowledge to support sustainable management and conservation.

Active hydrothermal vents ecosystems host rare, endemic, and fragile species adapted to life in extreme conditions (Van Dover, 2000). Because of these characteristics, hydrothermal vents are often referred to as examples of Vulnerable Marine Ecosystem (FAO, 2009) and were included in the OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR, 2010). Until very recently, deep-sea research was the main threat to these ecosystems (Glowka, 2003) but the recognition that the hydrothermal vents could provide a valuable source of scarce metals has become increasingly widespread in recent years (Petersen et al., 2016) and can pose serious threats to these ecosystems in a near future (Van Dover, 2014; Levin et al., 2016). In fact, large sources of copper, zinc, silver and gold ores have been identified in Seafloor Massive Sulphide deposits at deep-sea hydrothermal vents in many areas around the world (Hannington et al., 2011), including along the Mid-Atlantic Ridge (MAR) south of the Azores (Cherkashov et al., 2010).

Because of its ecological and biological importance but also because of the growing threats posed to hydrothermal vents, there have been global growing efforts to protect them. The Azores Region of Portugal pioneered some of these efforts, and the creation of the Marine Park of the Azores in 2007 was one of the first examples of Marine Protected Areas that included hydrothermal vents. The hydrothermal vents Menez Gwen and Lucky Strike were included in the Azores Marine Park in 2011 as Nature Reserves and are protected against bottom contact fishing, deep-sea mining, dumping and other activities that may cause harm to the marine environment (DLR n.º 28/2011/A). The Rainbow vent field was declared as a Nature Reserves located in the continental shelf behind 200nm claimed by Portugal, but it lacks effective protection measures (DLR n.º 28/2011/A). In fact, the existing regulations only state that entities based in the Autonomous Region of the Azores may not authorize, finance or support any activities of an extractive nature or that may result in disturbance of the benthic ecosystems and benthic species. The Menez Hom, Famous, Saldanha, and Amar were included in the 2016 revision of the Azores Marine Park as part of the PMA13 MPA, but ***lack effective protection measures*** (DLR n.º 13/2016/A). In fact, ***deep-sea mining exploration activities are not prohibited*** in PMA13, but they require special permits as it would be necessary for any other area. It would be desirable ***that deep-sea mining exploration and exploitation would be fully prohibited inside the Azores Marine Park***, but mainly in the PMA 13 (which includes PMA2, 3 and 4) in PMA 12 and in PMA 11 (which included PMA 1).

The new Luso hydrothermal vent field may not host important mineral resources, but it's a unique field in the Azores characterized by low temperature, high hydrogen, and iron-rich fluids supporting unique (and probably new and endemic) biological communities. It is likely that the area of influence of the hydrothermal vent field is shaping the biological communities living in the background which is characterized by abundant balonomorph barnacles and diverse coral gardens composed by the bubble gum coral *Paragorgia* spp. and the soft coral *Anthomastus* c.f. *agaricus*. Because of these characteristics, the Luso hydrothermal vent field should be declared an MPA, classified as a Nature Reserve, and included in the Azores Marine Park. In fact, following the discovery of the Luso vent field in the Gigante seamount, scientists and other stakeholders called for full protection of the new vent field; the only one of its kind. The Regional Government of the Azores declared the Luso hydrothermal vent field as a Marine Protected Area fully ***protected from fisheries*** in September 2019 (Portaria n.º 68/2019). However, the regulation does not mention other activities rather than fisheries, and therefore ***deep-sea mining exploration and scientific research were not subject to specific rules or prohibitions***.

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Vulnerable Marine Ecosystems identified in the Azores by means of towed camera systems and recommendations for the protection of these ecosystems

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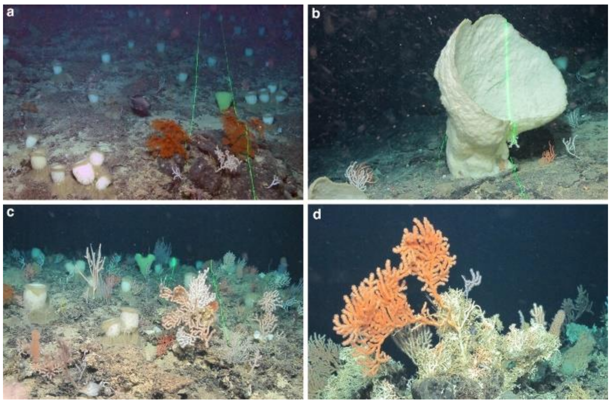
Executive Summary

February 2020

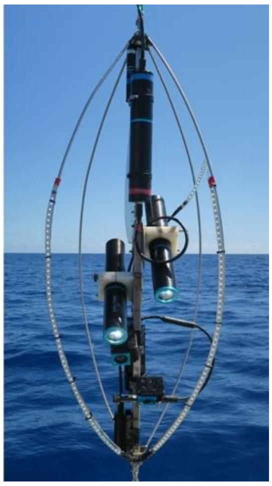
Executive summary

In order to comply with the provisions of the cooperation protocol between IMAR and the Blue Ocean Foundation, namely in which concerns with the Clause Six, (d) *submission to the Blue Ocean Foundation of Report on new Vulnerable Marine Ecosystems identified with the new video system and including recommendations for the protection of the new Vulnerable Marine Ecosystems identified*, we have prepared the attached report that is briefly summarized here.

Methodology



The Azores harbour a diverse number of benthic habitats, which are home to several coral gardens, cold-water coral reefs, sponge grounds and hydrothermal vents, among other relevant ecosystems. Such environments provide nursery and refuge areas for socio-economically important deep-sea fish species and can be hotspots for marine predators, vital to the stability and resilience of marine food webs. More than 450 seamount-like features have been identified inside the Azores EEZ, which imply that the efforts required to obtain a detailed characterization of the benthic habitats/communities found in the region are enormous. During the past decade, IMAR has assigned a great deal of resources into the exploration of the various deep-sea geomorphological features that can be found inside the Azores EEZ. Since 2010 IMAR has led or participated in over twenty oceanographic surveys that made use of imaging technology with the final objective of improving our understanding about the diversity and distribution of deep-sea benthic fauna.

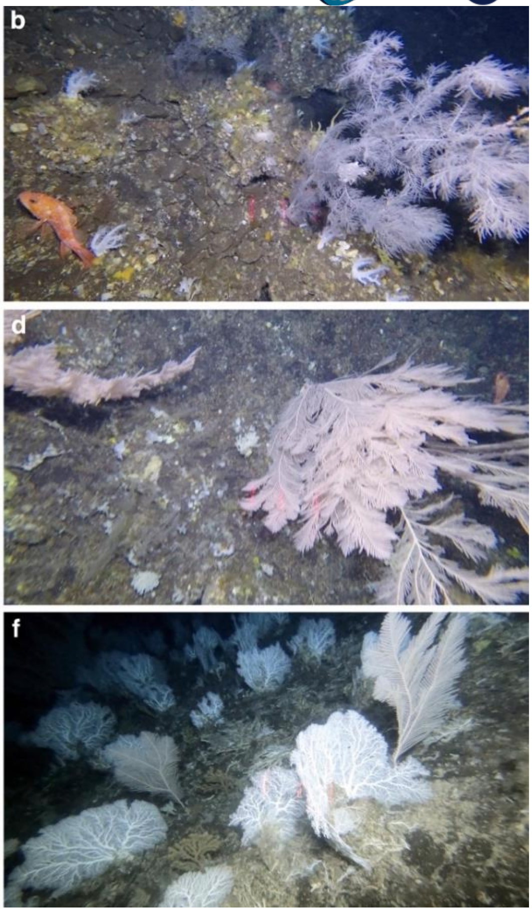


The video surveys have been mostly conducted with commercial Remotely Operated Vehicles, towed camera systems, or manned submersibles. More recently, IMAR developed a low-cost drift-cam system, providing local scientists with the possibility of exploring the slopes and summits of shallow seamounts and ridges, as well as shelf areas around the islands, without the need of large oceanographic vessels and high budgets. Until today, this low-cost video system has been successfully deployed over 160 times, covering almost 100 linear km of seabed and has generated more than 120 hours of seafloor images and was the main source of information used to elaborate this report. Here, we summarized the work developed by IMAR during the last decade in characterizing the Azores deep-sea benthic habitats, providing information on geographical patterns of species diversity across most of the EEZ. Overall, 25 underwater features have now been visited and preliminarily evaluated, including seamounts and ridges along the Mid-Atlantic Ridge and many island slopes and adjacent seamounts.

Deep-sea benthic communities in the Azores

Based on the video footage evaluated so far, the deep-sea areas of the Azores should be regarded as very diverse ecosystems, home to a large number of megabenthic species. Unlike other areas of the North Atlantic, the main species providing tri-dimensional structure to the seabed of the Azores correspond to large gorgonian octocorals. These species thrive in hard surfaces of summits and upper slopes of most seamounts and ridges explored, and are less frequently observed on the island slopes, especially those with high sedimentation rates.

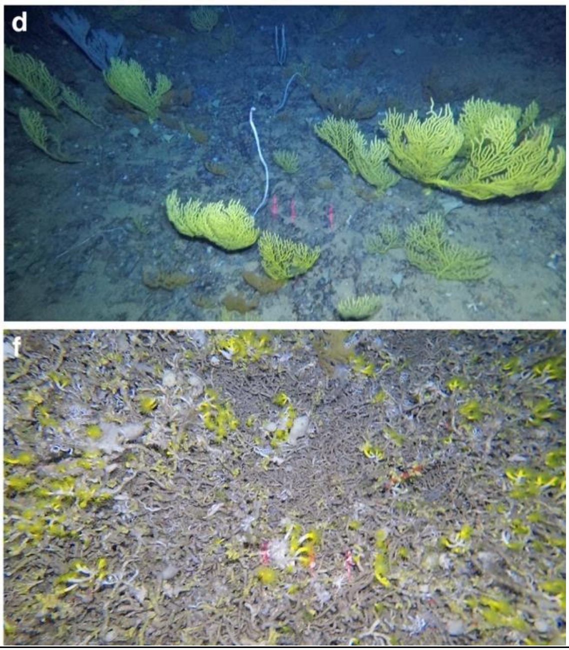
Octocorals can form very dense coral gardens, which are home to a wide variety of associated species, including mobile fauna such as fish and crustaceans. For instance, dense aggregations of *Dentomuricea* aff. *meteor* have been recorded in 5 areas so far, with the largest and most structurally complex populations observed in Cavala and Mar da Prata seamounts. Very large colonies of the bubble-gum coral *Paragorgia johnsoni*, generally accompanied by a high number of small soft and cup corals, have been observed in several seamounts of the MAR, especially in Beta and the Western ridge of the Gigante Seamount Complex. Ssome dense aggregations of the primnoids *Narella bellissima* and *Narella versluysi* can become very common, sometimes covering extensive areas. This is the case of Cavalo and Formigas seamounts, where very dense patches, have been observed for hundreds of meters. Other less-common octocoral dominated communities correspond to those characterized by the primnoids *Candidella imbricata* and *Paracalyptrophora josephinae*. The former tends to generate extremely dense patches over boulders, with high numbers of associated species, with a limited spatial coverage. The latter has only been observed forming dense aggregations in Voador seamount, with most colonies of a great size and showing little signs of fishing impacts. The deepest areas explored (1000-1400 m), generally at the base of the seamounts, are also home to another highly diverse mixed coral community, which includes several species of Plexauridae corals, black corals and bamboo corals. The densities of each species within this community is very variable, but the densest aggregations have been reported from a deep ridge east of Gigante and in Formigas seamount.



Besides the octocoral-dominated communities, the hydrozoan *Errina dabneyi* are also responsible for dense aggregations that lead to the development of structurally complex communities. This species is likely endemic to the Azores archipelago and has been observed forming highly dense patches in areas around islands of the central group, namely Capelinhos (W of Faial island) and the small seamounts southeast of Pico. Although scleractinian corals are not very conspicuous in the Azores, at least in terms of biomass, some species identified in the images can be considered characteristic of several benthic communities in at least two areas in the central group (Condor and SE Pico), besides the first record discovered in the Faial-Pico Channel.

Potential Vulnerable Marine Ecosystems identified in the Azores

Recognizing the vulnerability of deep-sea biodiversity, the United Nations General Assembly called upon States and Regional Fisheries Management Organizations to identify areas where Vulnerable Marine Ecosystems (VME) occur, or are likely to occur. The Food and Agricultural Organization developed criteria for defining what constitutes including Uniqueness or rarity, Functional significance of the habitat, Fragility, Life-history traits of component species that make recovery difficult, Structural complexity. Twenty-eight underwater features were assessed against each of the five FAO criteria for defining what constitute a VME using expert judgement.



Thirteen features out of the 28 features visually evaluated were identified as priority areas for conservation and could be considered potential VMEs. These features were generally characterized by great diversity of species and biological communities, with unique characteristics in terms of composition of endemic, rare or threatened species (FAO criteria 1), and/or communities composed of tall, and arborescent species that provide complex habitat for other species (FAO criteria 5). Fragility of the habitat-forming species (FAO criteria 3) was based on evidence of vulnerability to physical contact, such as accidental capture during long-line fishing, and the capacity of species for retraction, retention or re-growth or natural protection in some way.

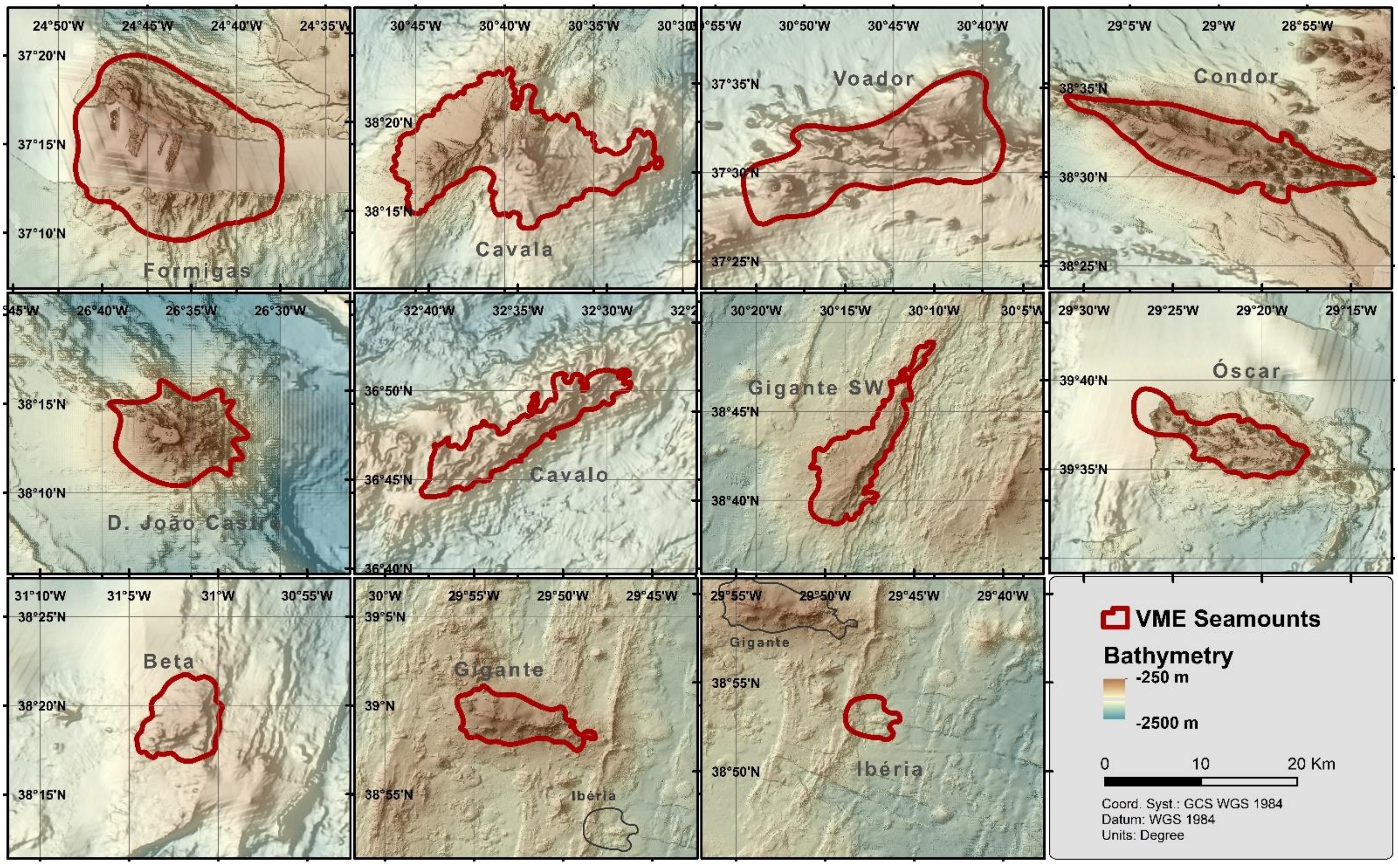
Management recommendations

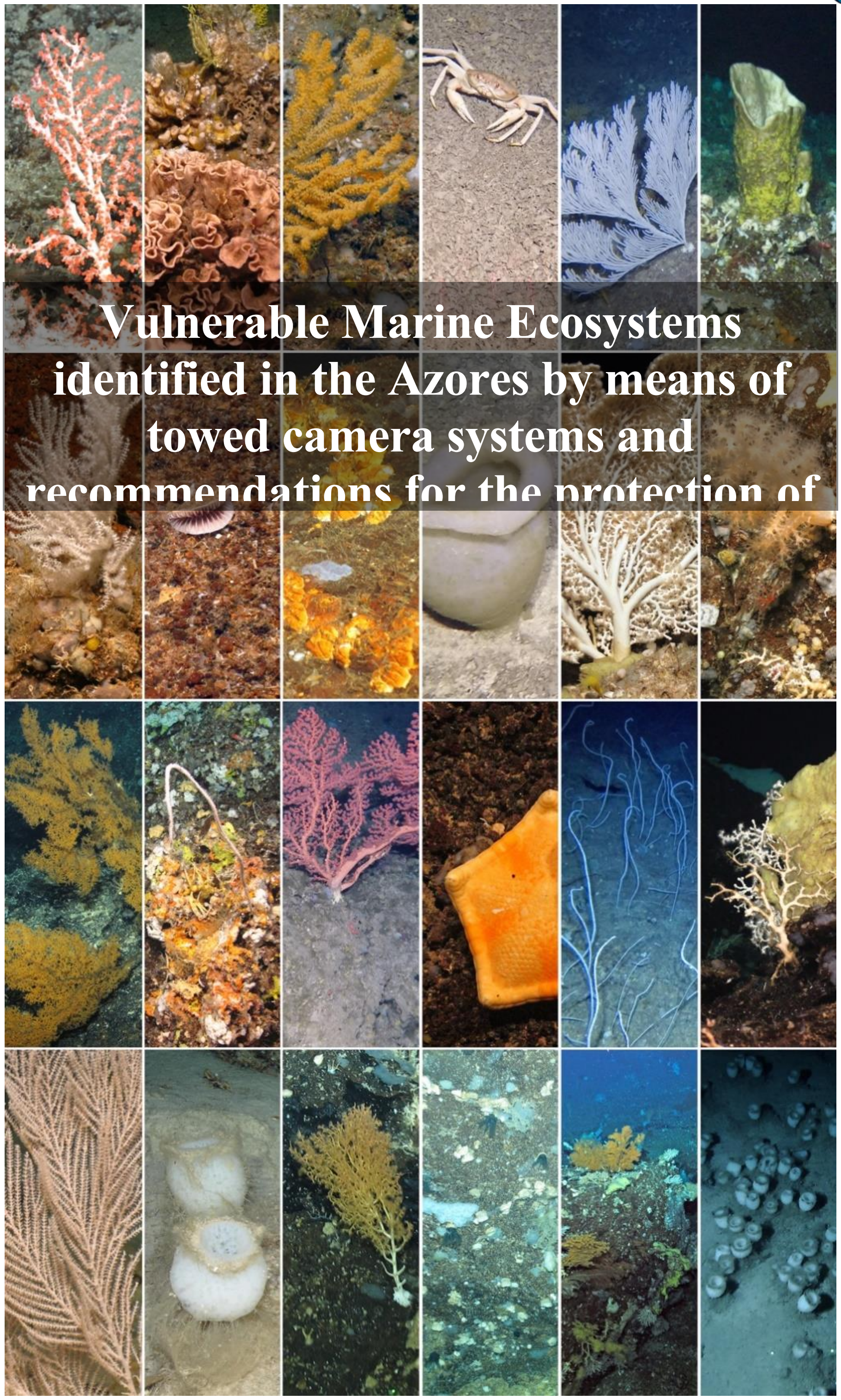
Based on the assessment described above, the large areas fitting the vulnerable marine ecosystem criteria were three portions of the Mid

Atlantic Ridge (Western ridge, Ridge east of Gigante, and Cavalo), eight seamounts (Oscar, Gigante, Cavala, Beta, Voador, Condor, D. João de Castro, and Formigas) and the deep-sea areas around Capelinhos (Faial island) and SE Pico Island. These latter two areas are located in the coastal areas (within 6nm from shore) and therefore outside the deep-sea spatial planning area. ***<u>The areas identified here as potential VMEs should be given high priority in the design of a network of Marine Protected Areas in the Azores</u>***.

Limitations

However, it should be noticed that the limited knowledge on deep-sea benthic communities in the Azores may hamper the proper identification of VMEs. Although the spatial extent of the underwater dives carried out until now is vast and covers a large number of underwater features, further efforts are still required understand how benthic diversity is organized along the depth gradient, especially below 800 m depth. In general, there was limited information to assess the life history and functional significance of many VME indicator species and communities due to major knowledge gaps on the reproductive cycles, growth rates, reproductive output, larvae biology and dispersal, recruitment and their role in the functioning of the ecosystems such as nursery areas for other species, nutrient regeneration, and carbon remineralisation and sequestration. Therefore, continued scientific research is necessary to better understand the distribution, structural and functional role of deep-sea benthic communities and inform adaptive management and conservation policies.





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February 2020

Table of Contents

1. Introduction

The Azores harbour a diverse number of benthic habitats, which are home to several coral gardens, cold-water coral reefs, sponge grounds and hydrothermal vents, among other relevant ecosystems (Tempera et al., 2013). Such environments provide nursery and refuge areas for socio-economically important deep-sea fish species (Pham et al., 2015) and can be hotspots for marine predators, vital to the stability and resilience of marine food webs. More than 450 seamount-like features have been identified inside the Azores EEZ (Morato et al., 2008), which imply that the efforts required to obtain a detailed characterization of the benthic habitats/communities found in the region are enormous. Historically, our knowledge about the diversity and structure of the benthic invertebrate fauna of the Azores relied on samples collected using remote techniques, such as nets or sleds (Porteiro, 2009), or on the evaluation of specimens provided by the fishing fleet as bycatch (e.g. Sampaio et al., 2012). Advances in underwater robotics and imaging technology (Durden et al., 2016) have enabled us to visually investigate deep-sea habitats, exponentially improving our understanding about the ecology of benthic species, as well as the spatial extent of the communities they form.

During the past decade, IMAR has assigned a great deal of resources into the exploration of the various deep-sea geomorphological features that can be found inside the Azores EEZ, including several seamounts, ridges, slopes and hydrothermal vents. Since video platforms can descend hundreds to thousands of meters through the water column, images collected using these methods should be considered the most powerful tool currently at our disposal to generate information about the distribution of marine ecosystems along latitudinal, longitudinal and bathymetrical gradients. Therefore, video images should be regarded as the most versatile sampling strategy to generate large censuses of species and communities without damaging the organisms focus of study. For this reason, since 2010 IMAR has led or participated in over twenty oceanographic surveys that make use of imaging technology with the final objective of improving our understanding about the diversity and distribution of deep-sea benthic fauna (Figure 1). Some of these cruises have been performed in collaboration with other international institutions (e.g. NIOZ, IFREMER, GEOMAR, IEO) and supported by multiple national and international projects (e.g. Hermione, MeshAtlantic, MIDAS, ATLAS and MapGES, among others).

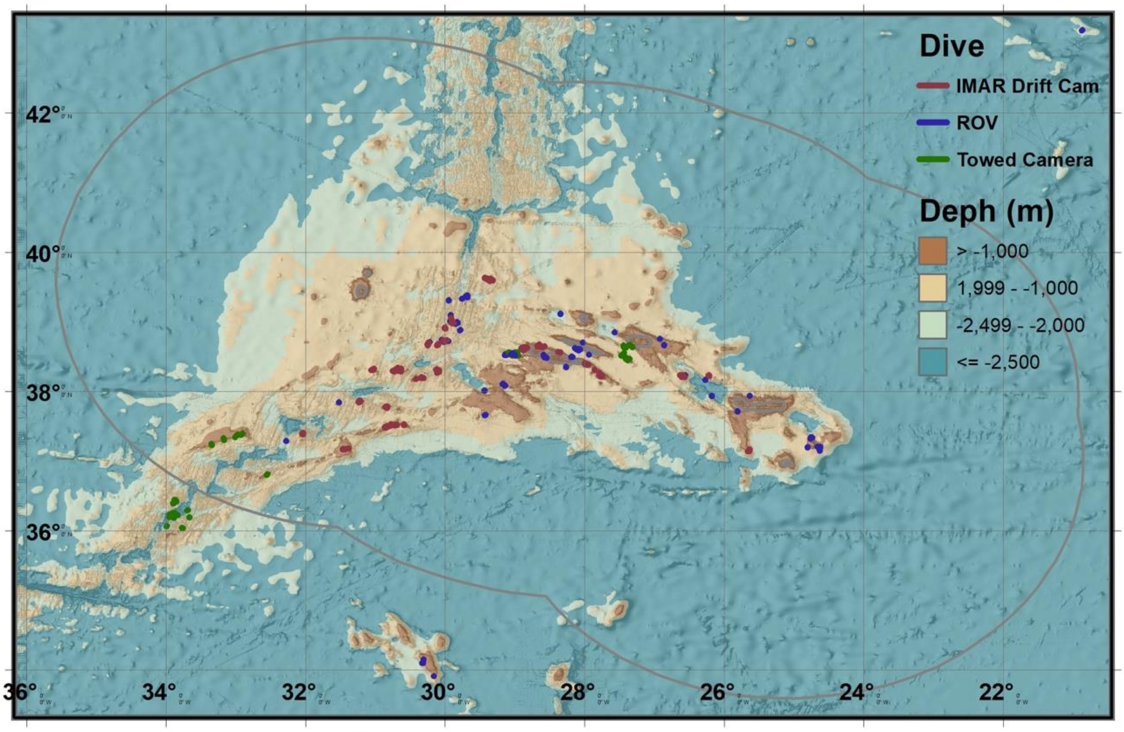

Figure 1. Location of the underwater dives carried out in the Azores region since 2010 to explore the seabed in the different oceanographic cruises that IMAR has organized or has taken part as a collaborator.

The video platforms employed to visually asses the seabed habitats mostly include commercial Remotely Operated Vehicles (ROVs, Figure 2a), which not only record high-quality images but also allow to selectively collect underwater samples to improve species identifications. Other less-versatile platforms, such as towed camera systems, have also been employed in several occasions (Figure 2b). These systems allow for larger areas of the seafloor to be evaluated, since they generally move along the seabed at a constant speed following the position of the vessel. Manned submersibles, such as LULA 1000, based in the harbor of Horta (Faial), have also been used to explore deep-sea habitats, mainly around the islands of the central group. These platforms are especially indicated for the study of benthic communities dwelling in complex relieves, such as vertical walls and crevices, where ROVs and tow cams connected to the vessel via an umbilical may face serious difficulties. More recently, IMAR has also developed a low-cost drift-cam system (Figure 2c) that can record video images down to 800 m depth, providing scientists with the possibility of exploring the slopes and summits of shallow seamounts and ridges, as well as shelf areas around the islands, without the need of large oceanographic vessels and high budgets. The drift-cam system has been designed to reduce the possibilities of entanglement in lost or abandoned fishing lines, one of the major issues encountered when surveying the deep seabed of the Azores. Regardless of its overall low cost (especially if compared to commercial ROVs), the drift-cam system is equipped with a 4k resolution camera that generates high quality images of the benthic fauna, as well as a powerful lightning system that generates sufficient ambience light to film from a distance of 2-3 m to the seabed. Until today, this low-cost video system has been successfully deployed over 160 times, covering almost 100 linear km of seabed and has generated more than 120 hours of seafloor images.

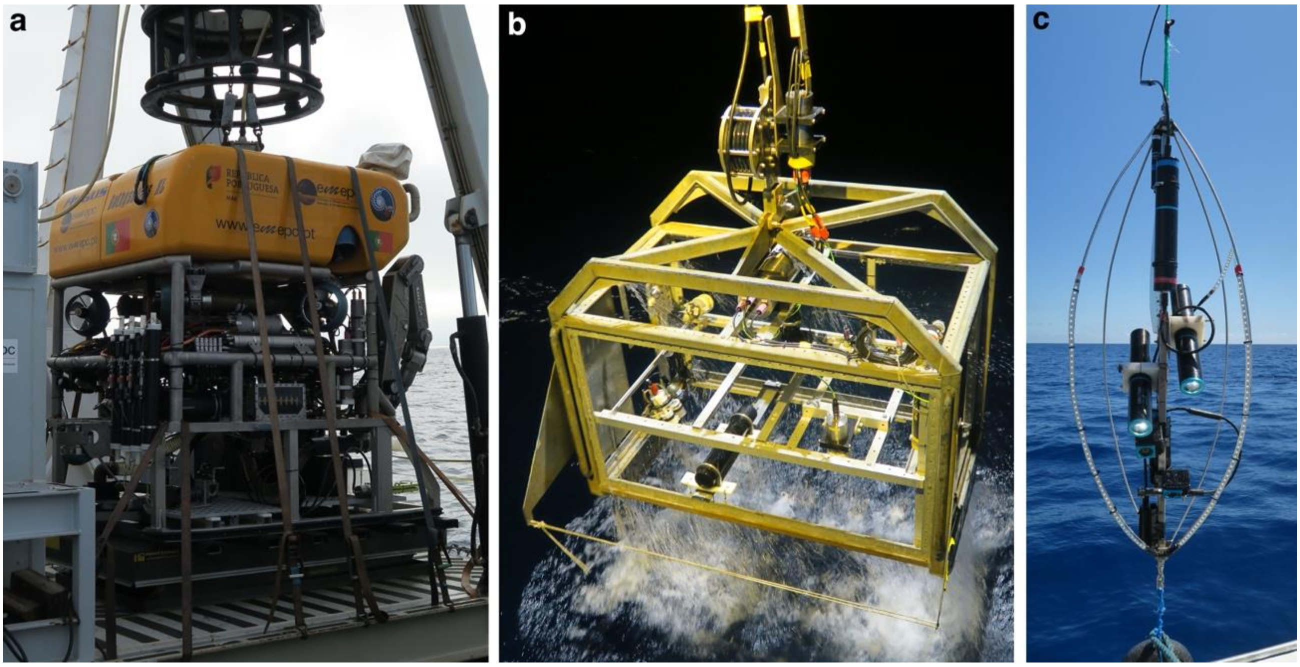

Figure 2. *Some of the video platforms used to explore deep-sea habitats of the Azores. (a) ROV Luso, from Portuguese Task Group for the Extension of the Continental Shelf. (b) Hopper towed camera system, from NIOZ (Holland). (c) Low-cost drift-cam system developed at IMAR-UAz.*

Not considering the historical knowledge about the benthic fauna of the Azores, the amount of area visually explored until very recently corresponded to only a small fraction of the EEZ, and the last few years have seen an exponential increase in the number of areas investigated. The present report summarizes the work developed by IMAR during the last decade in characterizing the Azores deep-sea benthic habitats, providing information on geographical patterns of species diversity across most of the EEZ. Overall, 25 underwater features have now been visited and preliminarily evaluated, including seamounts and ridges along the Mid-Atlantic Ridge and many island slopes and adjacent seamounts. The information of this report has been structured in 3 large study areas for an easier interpretation: Mid-Atlantic Ridge, islands of the Central group (Faial, Pico, São Jorge, Graciosa and Terceira) and islands of the Eastern group (São Miguel and Santa Maria).

Although the spatial extent of the underwater dives carried out until now is vast and covers a large number of underwater features, further efforts are still required understand how benthic diversity is organized along the depth gradient, especially below 800 m depth. The number of seamounts for which video data is available past those depths is still limited, with only a few representatives on the Mid-Atlantic Ridge (Gigante Seamount Complex), the central group (Condor and São Jorge de Fora seamounts) and eastern group (Formigas seamount). Furthermore, there are still some knowledge gaps around the islands that make up the western group (Corvo and Flores), for which no data is currently available, as well as those seamounts and ridges located on the Mid-Atlantic ridge north of Oscar seamount (39º 35' N). Most of the sampling effort will be placed on these areas in the forthcoming surveys.

2. Mid-Atlantic Ridge

The Mid-Atlantic Ridge (MAR) stretches for around 850 km inside the Azores EEZ. The number of seamounts and ridges that can be found along its path is extensive, and for this reason a large sampling effort has been placed in this area. Until now, 18 features have been evaluated, including 6 seamounts/ridges that belong to the Gigante Seamount Complex. The location of all the features described in this report along the MAR is shown in Figure 3. The extension of each geomorphological feature is shown in Figure 4.

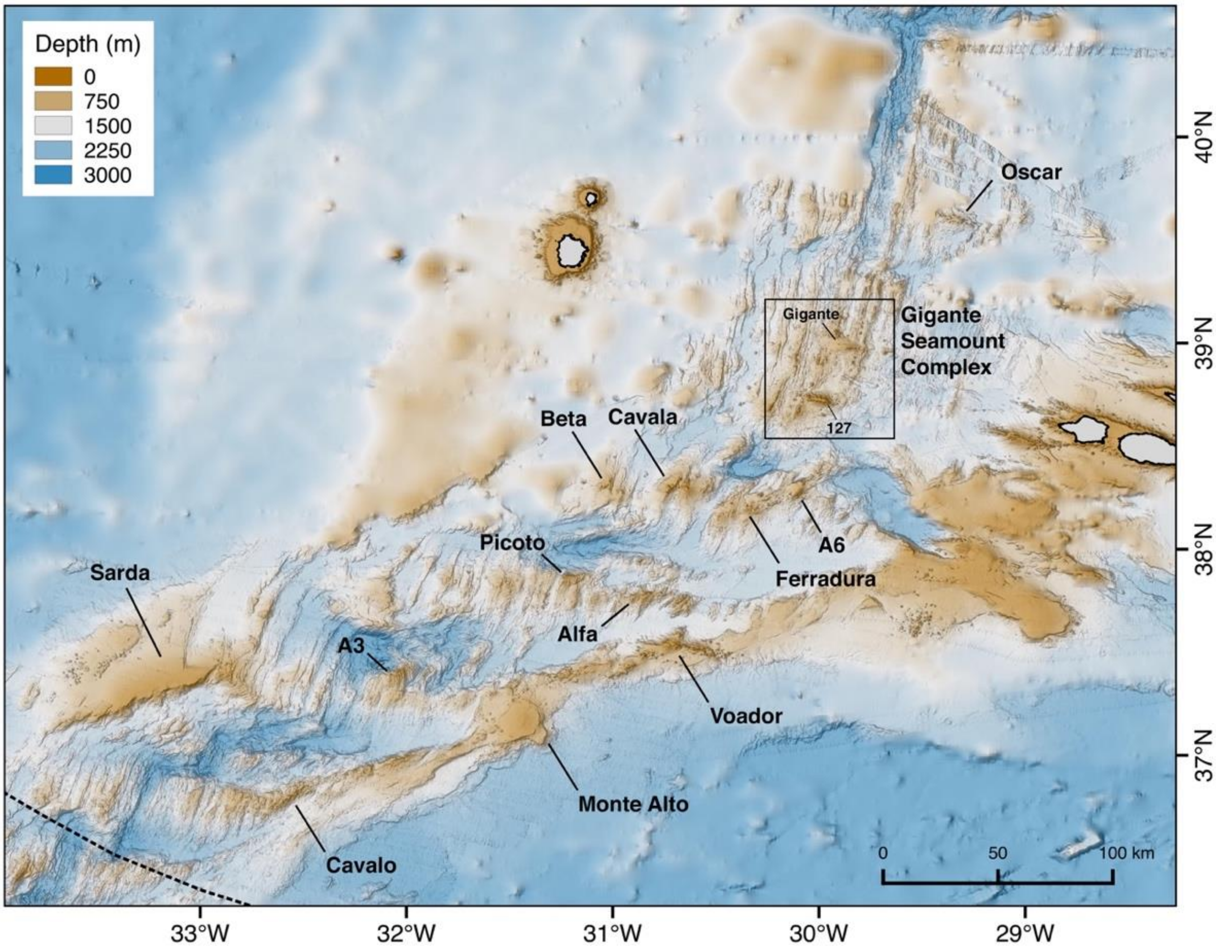

Figure 3. *Location of the different geomorphological features that have been evaluated along the Mid-Atlantic Ridge.*

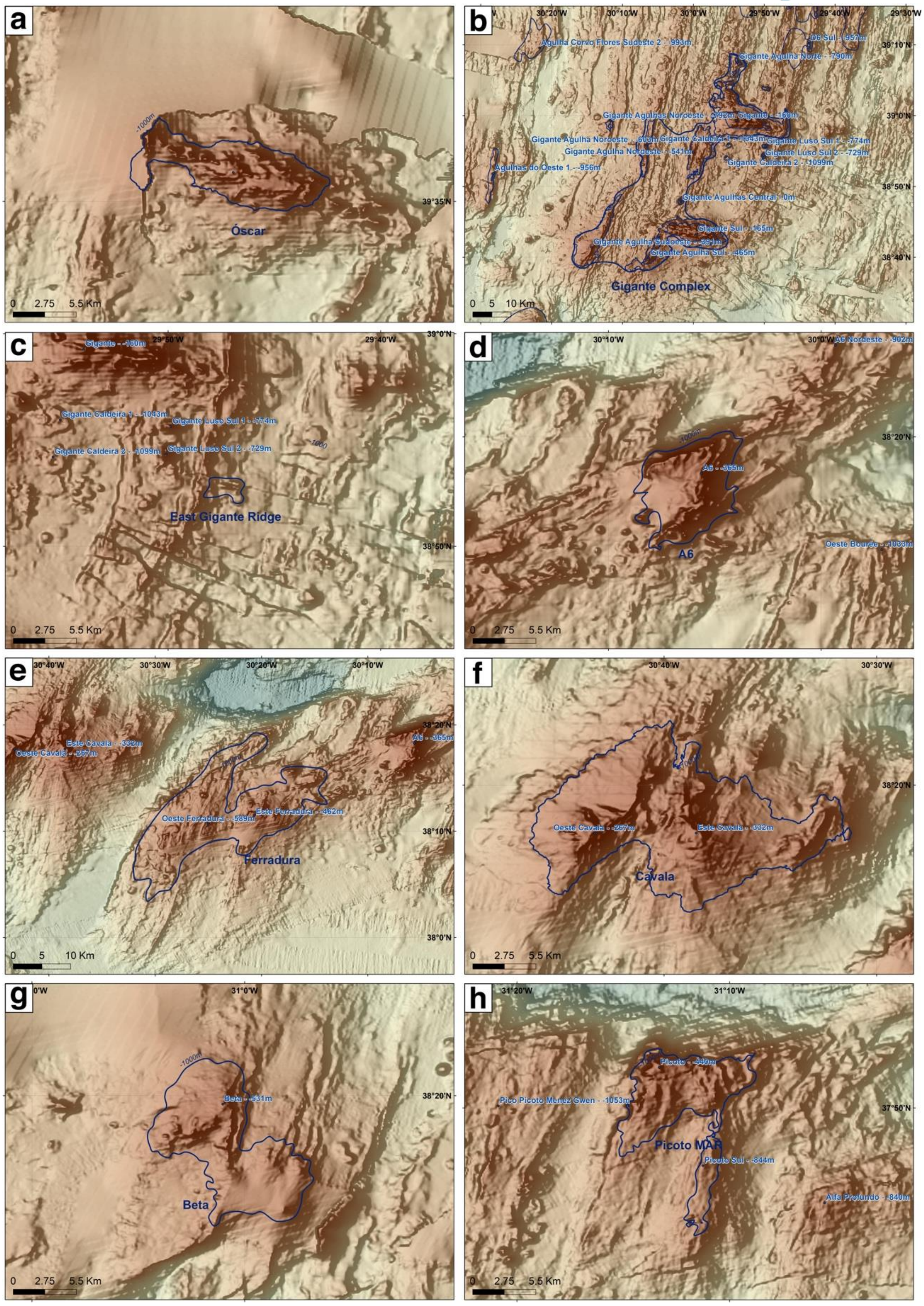

Figure 4. *Extension of each geomorphological feature evaluated in the Mid-Atlantic Ridge (black lines). (a) Oscar seamount. (b-c) Gigante Seamount complex. (d) A6 seamount. (e) Ferradura seamount. (f) Cavala seamount. (g) Beta seamount. (h) Picoto seamount. (i) Alfa seamount. (j) Voador seamount. (k) Monte Alto seamount. (l) A3 seamount. (m) Sarda seamount. (n) Cavalo seamount.*

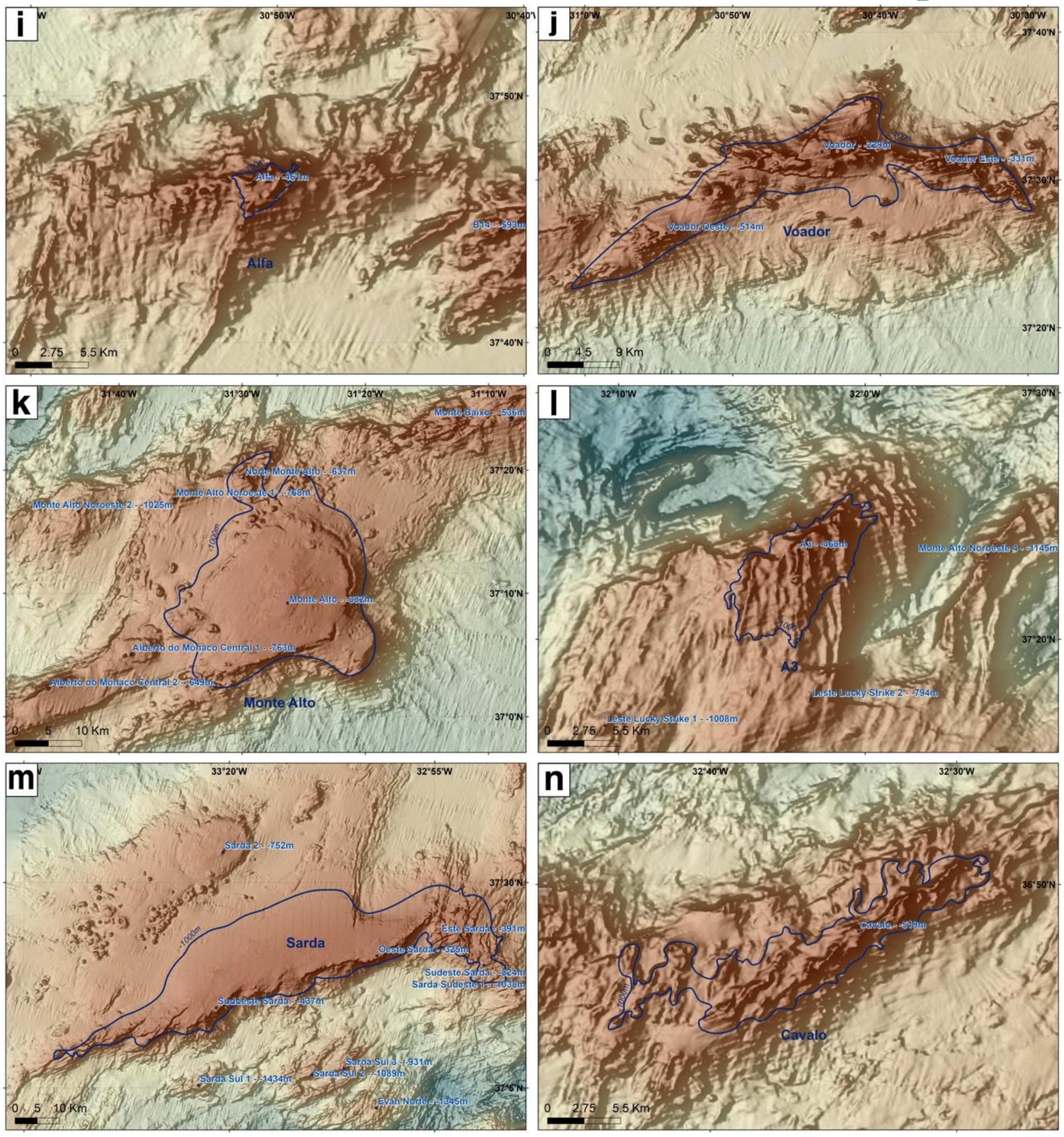

Figure 4. Continued.

These underwater features were visited during 6 different oceanographic cruises in the summers of 2018 and 2019 on board of the NRP Gago Coutinho, R/V Pelagia, B/O Sarmiento de Gamboa and N/I Arquipélago. In total, more than 130 underwater dives have been performed in these areas until now, with an asymmetric sampling effort (Table 1), being the Gigante Seamount Complex where most of the dives have taken place. In general, the summit areas of all seamounts/ridges have now been prospected, while maximum depths along the slopes vary across features. The deepest areas explored are located in Sarda seamount and in the Gigante Seamount Complex. Almost 120 dives (~90% of the total) have been carried out with the drift-cam system developed at IMAR, which was used to explore more than 10 features. Most dives targeted the seamount summits, but there have also been quite a few attempts to investigate the slopes down to 700 m. The ROV Luso was employed to evaluate the most important features of the Gigante Seamount Complex, with dives in Gigante and 127 seamounts, the western ridge and deep areas below 1000 m. The Hopper system was used to explore the seamounts located on the southernmost areas of the Mid-Atlantic Ridge (Sarda and Cavalo), and although only 5 dives have been performed there, the area explored is relatively large.

__Table 1.__ Number of dives and platform used to explore each of the seamounts/ridges of the Mid-Atlantic Ridge. Depth indicates the shallowest and deepest points reached across all dives in that feature. Features are ordered following a latitudinal gradient, from north to south.

Seamount/feature	Area (km^2)	Expedition	Year	Platform	Dives	Depth (m)
Oscar	52	MapGES 2	2019	Drift-cam	15	500 - 700
Gigante Seamount Complex	811	BlueAzores	2018	Luso ROV	9	310 - 825
		MapGES 2	2019	Drift-cam	31	180 - 795
		ExploSea	2019	Luso ROV	4	1000-1500
A6	47	MapGES 2	2019	Drift-cam	8	365 - 700
Ferradura	296	MapGES 2	2019	Drift-cam	7	475 - 665
Cavala	180	MapGES 2	2019	Drift-cam	15	335 - 675
Beta	84	MapGES 2	2019	Drift-cam	5	540 - 745
Picoto	56	MapGES 2	2019	Drift-cam	5	460 - 660
Alfa	8	MapGES 2	2019	Drift-cam	7	480 - 745
Voador	291	MapGES 2	2019	Drift-cam	14	250 - 580
Monte Alto	541	MapGES 2	2019	Drift-cam	6	385 - 555
A3	49	MapGES 2	2019	Drift-cam	6	450 - 550
Sarda	1117	Rainbow19	2019	Hopper	4	430 - 1150
Cavalo	86	Nico 12	2018	Hopper	1	600 - 700

2.1. Oscar seamount

Depth range explored: 500 - 700 m. 15 dives.

Oscar seamount is the northernmost geomorphological feature explored within the Azores EEZ so far. It is an elongated seamount that stretches for more than 12 km. Its seabed is mainly characterized by four coral-dominated benthic communities, distributed along the upper part of the slope and the summit areas. The most discernable community in hard substrates corresponds to that dominated by the primnoid coral *Callogorgia verticillata* (Figure 5a). In some areas, this octocoral species forms dense aggregations that spread along several tens of meters, with a large number of colonies displaying very large sizes, some of which above 1 m of height. Although some abandoned fishing lines have been observed, not many signs of fishing impact were detected on the *Callogorgia* colonies, with corals retaining all or most of their branches intact or in a healthy condition. This species is often observed in association with a few other smaller species that colonize the hard substrate available. It is very common to find the cup coral *Leptopsammia formosa* generating some very high-density patches, together with other soft-coral species, the cup coral *Desmophyllum dianthus* and various encrusting sponges (Figure 5b). The association between *Callogorgia verticillata* and the primnoid corals *Narella bellissima* and *Narella versluysi* is also common in Oscar seamount, especially at depths of 650-700 m depth.

In some hard substrates of the upper slope and on the summit, aggregations of the yellow sea fan of the genus *Acanthogorgia* reaching very high densities can also be observed (Figure 5c). In these aggregations, colonies place themselves with their branches oriented in the same position, most likely perpendicular to the direction of the dominant bottom current to maximize food intake. Another commonly observed species association corresponds to the small white coral *Pleurocorallium johnsoni* and the yellow laminate sponge cf. *Poecillastra compressa*. This community is mainly observed on hard substrates of the slope, and displays a high number of accompanying anthozoans and sponges, all of which of a small size. Some of the species identified correspond to the soft coral *Pseudoanthomastus* cf. *agaricus* and the black corals *Stichopathes* cf. *gravieri* and *Paranthipathes hirondelle* (Figure 5d), this last species reaching the highest densities recorded throughout the whole MAR to date. A yellow sea star of the Goniasteridae family is also commonly observed along the rocky outcrops of the slope (Figure 5d), not always as solitary individuals but in aggregations of 3-5 specimens. Also on some summit areas, whip corals of the species *Viminella flagellum* have been identified, in this case forming aggregations with large porifera (mostly cf. *Characella pachastrelloides* and *Craniella longipilis*) similar to those observed in other seamounts of the MAR.

The presence of coral rubble deposits in Oscar seamount is common, varying in size and frequency across the different areas explored. In some cases, the amount of coral rubble is so great that covers the whole substrate available (Figure 5e). Although most branches seem to be of a very large diameter, the cold-water species that have originated these coral rubble deposits still remain unclear. Not many megabenthic invertebrates were reported from the video footage in the coral rubble deposits. However, a more detailed analysis of its associated macrofaunal based on physical samples would be interesting to better understand the role that these deposits play in the overall diversity of the seamount. Soft-bottom areas found in between the coral deposits, mainly composed of sand and small gravels, were colonized by scleractinians of the genus *Flabellum*. Their density across the mound is very hard to estimate from video images due to the mimicry effect that this species has with the substratum, but individuals tend to appear scattered along the seafloor.

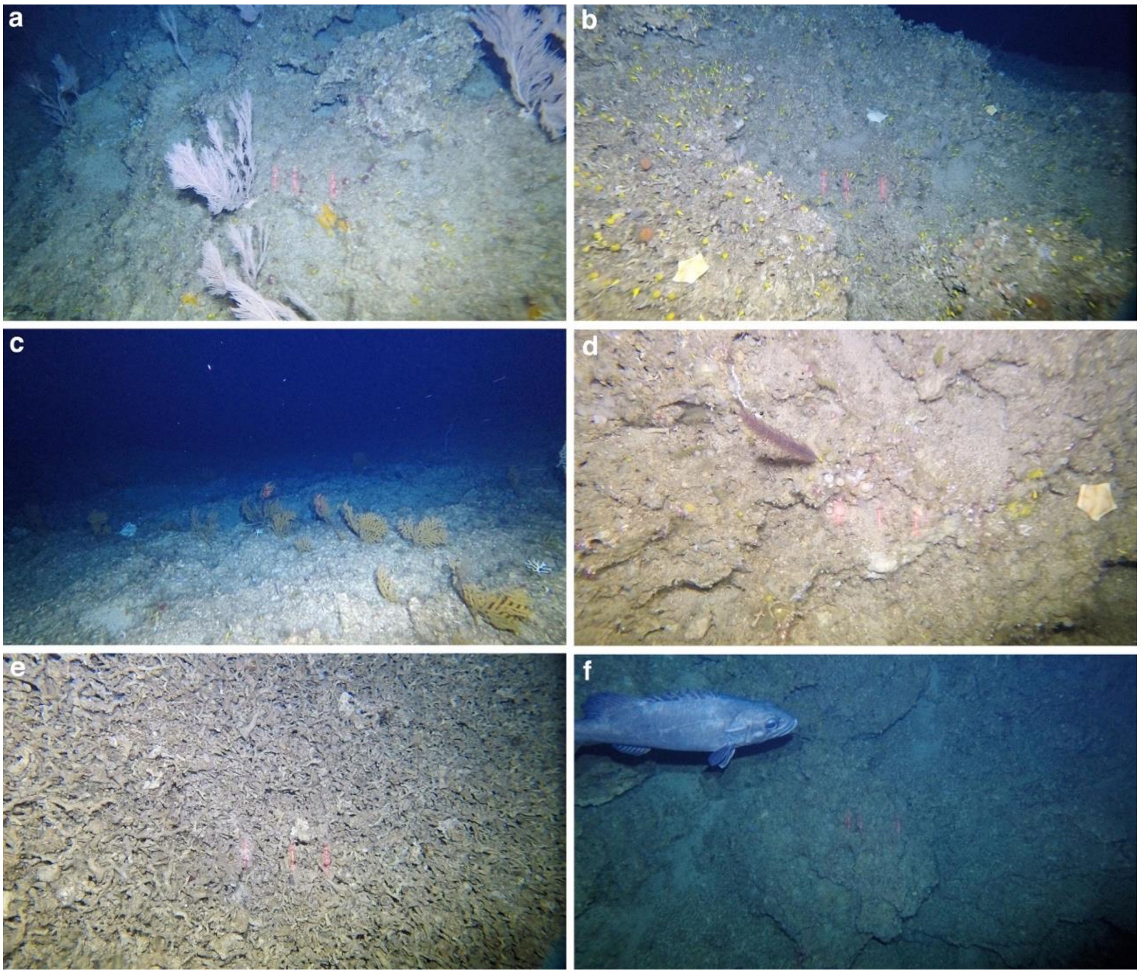

Figure 5. *Images showing some of the benthic communities that have been identified in Oscar seamount. (a) One of the numerous aggregations of the large gorgonian coral Callogorgia verticillata on hard substrates on the upper part of the slope. (b) Outcropping rock colonized by the yellow cup coral Leptopsammia formosa, a very common scleractinian species found in the Callogorgia verticillata aggregations. (c) Dense patch of the sea fan Acanthogorgia sp. on the summit area. (d) Colony of the black coral Parantipathes hirondelle together with a sea star of the Goniasteridae family, both species commonly observed on sloping hard grounds. (e). Large deposits of coral rubble. (f) A fish of the species Polyprion americanus gently swimming in front of the camera. © Drift cam, IMAR/Okeanos UAç.*

2.2. Gigante Seamount Complex

Depth range explored: 180 - 825 m. 44 dives.

The Gigante Seamount Complex is located between the islands of Flores and Faial, in the MAR. It is mainly composed of two ridge-like seamounts (Gigante and 127) and several smaller ridges. Both seamounts have a similar morphology, rising 800 m from the seafloor to water depths of approximately 150 m, and follow the main trend of the Azores volcanic emplacement direction (~110-120º). The other smaller ridge-like structures are oriented in a N-S direction and have more abrupt geomorphologies.

2.2.1. Gigante seamount

The deepest zone explored on the north-eastern flank (730-600 m) alternates detritic bottoms (with scarce presence of solitary corals) and several types of hard substrates. Lithic rocks host the highest diversity of organisms, although at not very high densities. *Narella* spp. (only below 650 m), *Callogorgia verticillata*, Acanthogorgiidae, *Pleurocorallium johnsoni* and *Pseudoanthomastus* cf. *agaricus*, together with massive (unidentified) and tubular (cf. Rossellidae spp. and cf. *Regadrella phoenix*) sponges are found scattered around the lithic substrate, occasionally forming denser aggregations. *Pleurocorallium johnsoni* (possibly mixed with small *Paragorgia johnson*i colonies), cf. *Poecillastra compressa* and, to a lesser extent, *Acanthogorgia*, *Pseudoanthomastus* cf. *agaricus* and Nidaliidae species, are the dominant organisms on intact lava balloons (Figure 6a). Crumbled lava balloons show the lowest diversity among hard substrates, with visible resident organisms limited to small Porifera and Antipatharia (*Parantipathes hirondelle* and *Stichopathes* cf. *gravieri*) (Figure 6b). Large crevices, at around 700 m, seem to host peculiar communities dominated by large *Placogorgia* spp. and reddish Caryophylliidae. Between 600-550 m, *Paragorgia johnsoni* in the red and white morphs together with vent associated cirripeds become the most abundant type of aggregation. These coral colonies reach considerable sizes especially on vertical rocky walls. Hydrothermal vent fields were found at around 570 m and presented little associate megafauna in their immediate proximity.

The deepest zone explored on the south-eastern flank (730-620 m) mostly consists of detritric beds colonized by *Flabellum* species, while sparse boulders present coral assemblages of moderate diversity (Caryophyllidae, *Anthomasthus* cf. *agaricus*, Clavularia spp., *Parantipathes hirondelle*, *Swiftia* spp. and *Muriceides* spp.) and a similar sponge composition as in the deeper part of the north-eastern flank. A little field of the sponge *Pheronema carpenteri* inhabit the seafloor at around 690 m (Figure 6c). Larger rock cover starts from 620 m, with a few rocky walls colonized by the deep-sea oyster cf. *Neopycnodonte zibrowii*. Sparse colonies of Coralliidae are also encountered at this depth. Similar to the other two flanks, the first colonies of *Viminella flagellum* and high densities of small Porifera are associated with medium size rocky outcrops starting from 550 m while patches of pebble are mostly covered by encrusting sponges. Moving shallower, larger sponges such as *Leiodermatium lynceus*, *Characella pachastrelloides*, cf. *Neophrissospongia nolitangere* and othr arborescent species start to appear (Figure 6d). Coral aggregations become more frequent above 390 m counting 4 families of gorgonians (Plexauridae, Primnoidae, Ellisellidae and Acanthogorgiidae). At this and shallower depths the most prominent aggregating coral species are *Callogorgia verticillata*, *Candidella* cf. *imbricata*; *Dentomuricea* cf. *meteor*, *Muriceides* spp., *Acanthogorgia* cf. *hirsuta* and *Viminella flagellum*. Also the black corals *Antipathes* spp. and *Elatopathes* cf. *abietina* are common at these depths.

The deepest zone explored on the north-western flank (730-690 m) presents characteristic aggregations of the Primnoidae species *Narella versluysi* and *Narella bellissima* (Figure 6e), mixed with *Pleurocorallium johnsoni*, cf. *Poecillastra compressa*, *Pseudoanthomastus* cf. *agaricus* and, more rarely, with the sponges *Pheronema carpenteri* and cf. *Poecillastra compressa*, small Acanthogorgiidae colonies and soft corals (Nidaliidae spp.). Above 690 m depth, *Narella* species become rarer; benthic aggregations present increasing abundances of small globular and incrusting sponges, large tubular (cf. *Characella pachastrelloides*), flabellate (cf. *Neophrissospongia nolitangere*) and massive (unidentified) sponges, *Pleurocorallium* cf. *johnsoni* and small

Alcyoniidae species. Above 550 m, the coral species *Viminella flagellum*, *Acanthogorgia* cf. *hirsuta* and *Pleurocorallium johnsoni*, Alcyoniidae spp., smaller Plexauridae and Primnoidae, together with cf. *Characella pachastrelloides*, unidentified massive sponges and rarer black coral colonies of *Elatopathes abietina* form the dominant aggregations. Above 450 m, the scleractinian *Enallopsammia rostrata* substitutes *Pleurocorallium johnsoni* while above 400 m large colonies of *Dentomuricea* cf. *meteor* and the sponge cf. *Leiodermatium pfeifferae* become rather common. Overall, the portion the north-western flank shallower than 500 m seems to constitute a hotspot of benthic diversity and abundance (Figure 6f).

2.2.2. 127 seamount

The deepest zone explored on the southern flank (600-500m) is characterized by sedimentary substrate colonized by several species of solitary corals of the genus *Flabellum*. The sparse rocky outcrops are of small sizes and colonized mostly by encrusting and small globular sponges (<5 cm) and, occasionally, by larger sponges. Coral colonies are scarce and mostly belong to the families Aphanipathidae and Acanthogorgiidae (Figure 6g). From 500 to 400 m depth, larger boulders become more frequent and are associated with several species of encrusting sponges and occasional colonies of *Viminella flagellum*, Aphanipathidae and Acanthogorgiidae. Soft sediments remain predominant and are characterized by *Flabellum* spp., arborescent sponges and cf. *Macandrewia azorica*. The peak at around 360 m is characterized by more extensive rocky outcrops still with a large preponderance of encrusting and globular sponges. Small Plexauridae colonies and *Viminella flagellum* are also abundant. These areas host several individuals of the deep-water shark *Dalathias licha* and may represent an important area of aggregation for this species (Figure 6h).

The deepest zone explored on the north-western flank (680-580 m) present a substrate dominated by large basaltic lava balloons. Characteristic aggregations at these depths count, in order of abundance, the flabellate sponge cf. *Poecillastra compressa*, the Scleraxonia *Pleurocorallium johnsoni*, soft corals of the genus *Pseudoanthomastus* and of the family Nidaliidae, the Calcaxonia *Narella versluysi* (present only below 650 m). Encrusting sponges are not as abundant as on the other two flanks. Solitary corals and large aggregations of the fish species *Hoplostethus mediterraneus* are found at depths shallower than 610 m on soft sediments (Figure 6i). Again, at around 580 m the first small colonies of the whip coral Viminella fla*gellum* begin to appear, forming denser and larger patches above 550 m, while cf. *Poecillastra compressa* and *Pleurocorallium johnsoni* become rarer above these depths. The abundance and diversity of encrusting sponges increases as depth decreases and, especially above 450 m, becomes the dominant fauna of many areas (occasionally in association with *Viminella flagellum* and the black coral *Elatopathes abietina*).

The deepest zone explored on the north-eastern flank (770-450 m) is largely sedimentary with the predominant organisms belonging to the genus *Flabellum* and *Deltocyathus* (Figure 6j). The rare large boulders at these depths host small globular sponges and, occasionally, Acanthogorgiidae and Paramuriceidae species. Starting from 650 m, the boulders present are not as covered by sediment as deeper ones and are largely covered by several species of encrusting sponges and, occasionally, by larger lithistid sponges (e.g., cf. *Neophrissospongia nolitangere*). At around 540 m the first small colonies of *Viminella flagellum* and the soft corals *Bellonella* and *Pseudoanthomastus* start to appear. From 480 m, at intermediate slopes, hard substrate becomes more abundant, however, possibly because of high sediment deposition, most of the colonizing organisms remain of small sizes and mainly consist of small Porifera and little *Viminella flagellum* colonies. Moving toward shallower depths the density of sponges increases but the overall sizes remain small. The shallowest depths explored (400-300 m) are characterized by hard substrates, larger *Viminella flagellum*, high densities of encrusting and small globular sponges, together with rarer patches of large octocorals of the species *Callogorgia verticillata* and *Candidella* cf. *imbricate*, as well as some larger flabellate (cf. *Neophrissospongia nolitangere* and *Leiodermatium pfeifferae*) and tubular (cf. *Characella pachastrelloides*) sponges (Figure 6k).

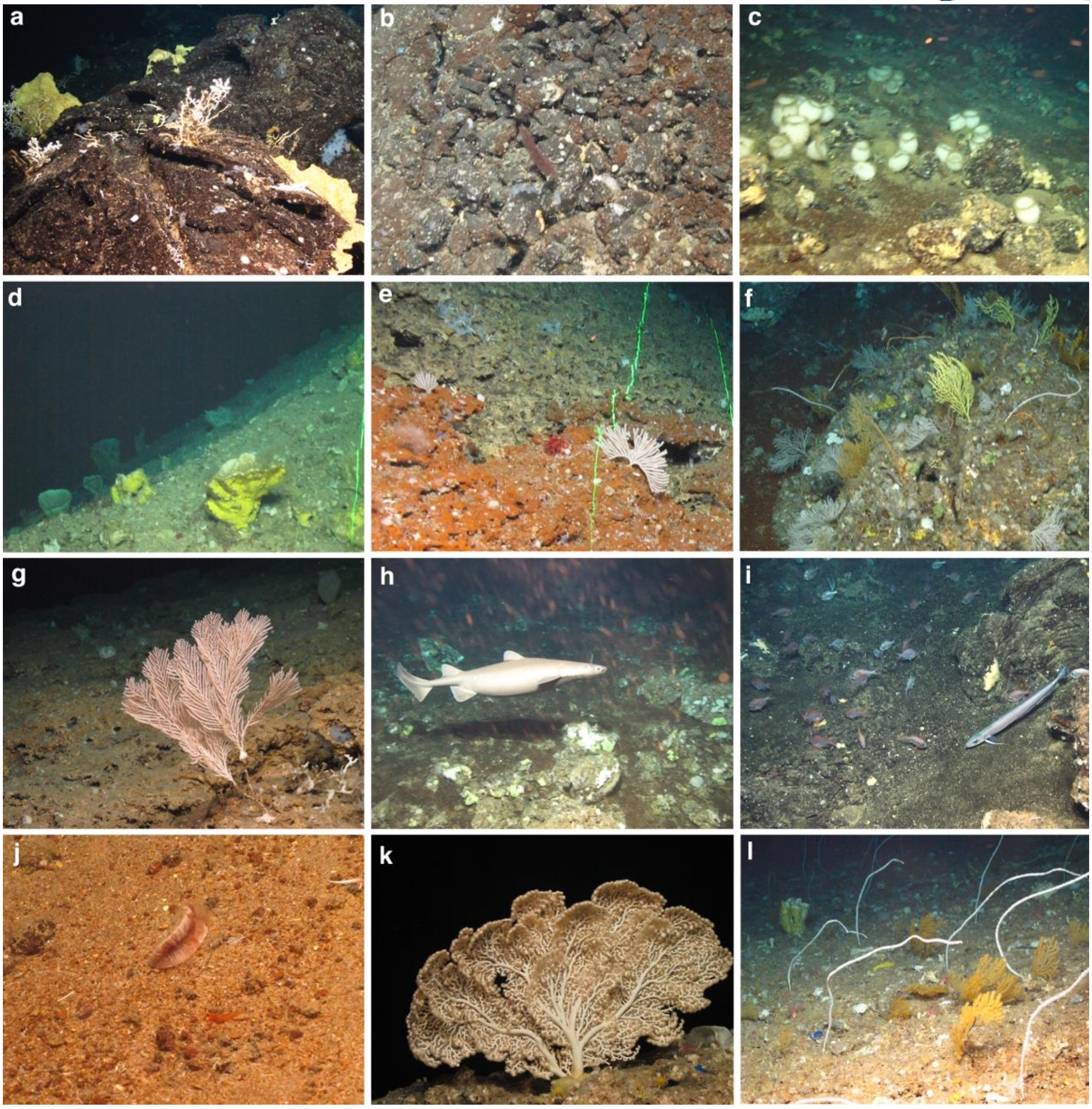

Figure 6. *Images showing some of the benthic communities that have been identified in the Gigante Seamount Complex. (a) The laminate sponge cf. Poecillastra compressa and the octocoral Pleurocorallium johnsoni on lava balloons. (b) The black coral Parantipathes hirondelle on crumbled basaltic rock. (c) Aggregation of the large glass sponge Pheronema carpenteri. (d) Large tubular sponges cf. Characella pachastrelloides. (e) Primnoids of the species Narella bellissima. (f) Very diverse patch on a large boulder with the octocorals Viminella flagellum, Candidella cf. imbricate, Dentomuricea aff. meteor and encrusting sponges. (g) A solitary colony of the primnoid Callogorgia verticillata. (h) Deep-water shark Dalathias licha. (i) One specimen of Molva macrophthalma in an aggregation of the deep-sea fish Hoplostethus mediterraneus. (j) One of the few solitary scleractinians found on soft sediments, likely to be Flabellum chuni. (k) A large Paragorgia johnsoni colony found on the slopes of the western ridge. (l) Coral garden on the top of the western ridge with Viminella flagellum and Acanthogorgia cf. hirsuta, together with a few sponges of the species Characella pachastrelloides. Credits: © ROV Luso/EMEPC / 2018 Oceano Azul Expedition.*

2.2.3. Western ridge

At about 560 m on lithic substrate, a great variety of unidentified massive, encrusting and globular sponges can be observed, as well as a small Dendrophylliidae (likely *Leptopsammia formosa*), *Pseudoanthomastus* cf. *agaricus* and Plumulariidae species. Two main cold-water coral assemblages can be identified: one dominated by Scleraxonia species, with dominance of large *Paragorgia johnsoni* colonies (Figure 6n), and the other by Holaxonia species, including *Anthothela*, *Swiftia* spp., *Acanthogorgia* sp. and *Pseudoanthomastus* spp. As depth decreases, new Coralliidae species appear and larger sponges become more frequent. In particular, *Leiodermatium lynceus*, cf. *Characella pachastrelloides*, cf. *Neophrissospongia nolitangere*, cf. *Poecillastra* *compressa*, cf. *Pachastrella monilifera* and other large unidentified massive sponges, which become the most prominent organisms. The first loose aggregations of *Viminella flagellum* are encountered at about 460 m mixed with unidentified Coralliidae, *Pseudoanthomastus* cf. *agaricus* and Plumulariidae species. Gradually, *Viminella flagellum* aggregations become denser and Coralliidae species are substituted by *Acanthogorgia* and *Eguchipsammia* species (*Figure* 6o). *Nicella granifera*, other yellowish small Plexauridae, *Elatopathes abietina*, other Eliopathidae and *Dentomuricea* cf. *meteor* are also observed below 430 m depth.

2.2.4. Ridge east of Gigante seamount

The deepest portion of the MAR that has been explored is characterized by the presence of large, likely old, colonies of octocoral and black coral species and sponges. The seabed at 1400-1200 m depth is characterized by sandy substrates with visible pillow lavas and large accumulations of coral rubble. Cold-water corals sparsely colonized available hard substrates, with communities dominated by the black coral species *Leiopathes* sp., *Bathypathes* sp, *Stichopathes* sp., and the octocorals *Chrysogorgia* sp., *Iridogorgia* sp., *Acanella arbuscula*, *Candidella imbricata*, cf. *Paramuricea* sp., unidentified Plexauridae and the solitary scleractinian *Caryophyllia* sp. (Figure 7a). Sponge species in this area include *Pheronema carpenteri*, *Phakellia* sp., cf. *Hertwigia falcifera*, *Asconema* sp., *Regradella* sp. and an large white sponge likely to be *Phakellia robusta* (Figure 7b). Several individual of the sea pen cf. *Gyrophyllum hirondellei* have also been observed as part of this community. A large aggregation of the glass sponge *Pheronema carpentieri* occurrs at around 1220 m depth and occupies an area of approximately 50 m^2.

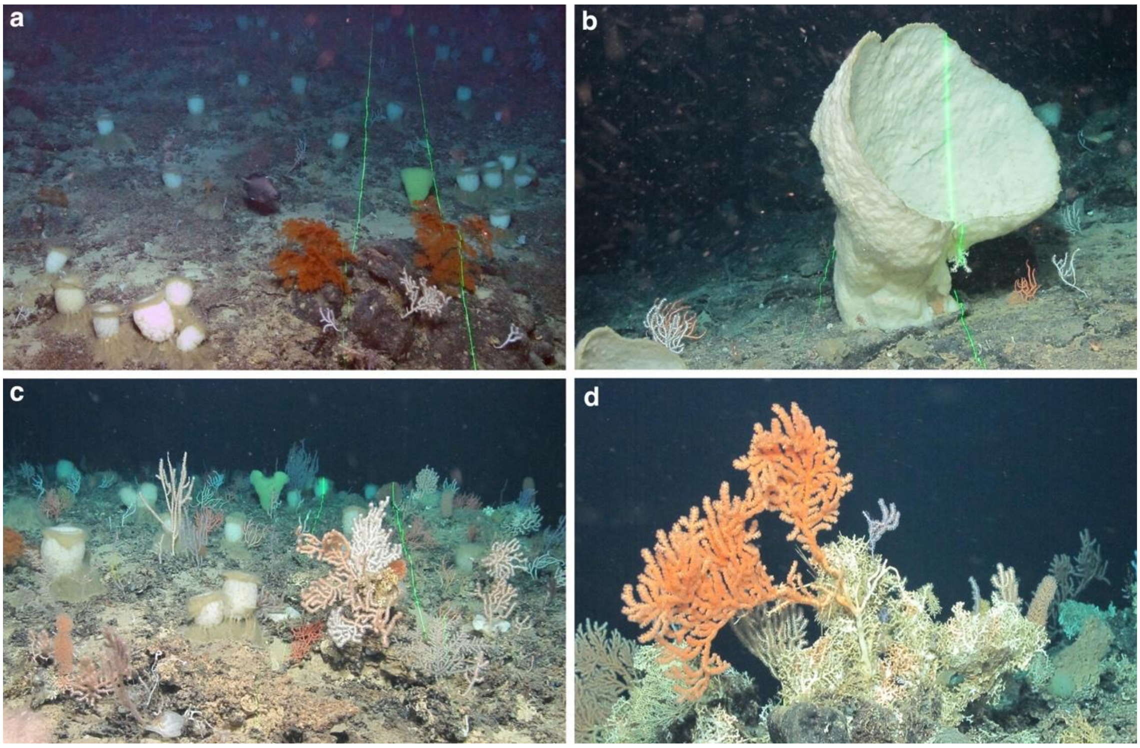

Figure 7. *Images showing some of the benthic communities that have been identified in the deep areas of the MAR. (a). Two large black corals of the genus Leiopathes with a few Pheronema carpenteri sponges in the background. (b) A very large laminate sponge likely to be of the species Phakellia robusta. (c) Mixed coral garden with several species of octocorals, black corals and bamboo corals. (d) Unidentified bamboo coral growing over the calcareous skeleton of a scleractinian coral. Credits: © ROV Luso/EMEPC, ExploSeas2 cruise.*

Pillow lavas become the dominant substrate at depths between 1220 and 1140 m and are colonized by highly diverse and extensive coral gardens composed of different species of the bamboo corals *Lepidisis* sp, *Keratoisis* sp., *Acanella arbuscula* and the octocorals *Iridogorgia* sp, *Chrysogorgia* sp, *Hemicorallium tricolor*, cf *Paramuricea* sp., *Pleurocorallium johnsoni* and several unidentified species of Plexauridae, likely representing new species to Science (Figure 7c-d). The scleractinians species *Enallopsammia rostrata*, *Caryophyllia* sp, *Desmophyllum dianthus*, *Madrepora oculata* and *Lophelia pertusa* can also be found at those depths, together with the black coral *Leiopathes* sp. It is estimated that the large colonies (1.5-2 m tall) of the bamboo coral *Keratoisis* sp. and the black coral *Leiopathes* sp. may have ages of several centuries to millennia, respectively. Associated fauna includes the echinoid cf. *Cidaris cidaris*, several Ophiuroidae, Asteroidae, Crinoidae, Hydrozoa, Bryozoa and the shrimp *Aristaeopsis edwardsiana*.

2.3. A6 seamount

Depth range explored: 365 - 700 m. 8 dives.

A large part of this seamount is characterized by the presence of coral rubble deposits (Figure 8a), whose origin and causes are still to be determined. Some of the colonies seem to belong to the hydrocoral species *Errina dabneyi*, but further analyses are yet to be undertaken. The vast majority of soft bottom areas have coral pieces scattered over the seafloor, in some cases covering the entire surface available, a situation also observed in some rocky areas. At 600 m depth, aggregations of the glass sponge *Pheronema carpenteri* can be found in between the pieces of dead corals, although this sponge species displays lower density values than those recorded in other areas of the Azores. Other soft-bottom areas in between the scattered coral rubble, with a high percentage of sand, also host populations of the scleractinian *Flabellum* sp., usually accompanied by the soft coral *Pseudoanthomastus* cf. *agaricus*. Deep areas of the seamount are characterized by large rocky outcrops, in some cases generating very steep slopes, which are mostly colonized by a large number of sponge species, predominantly encrusting and small erect, but also by laminate species of larger sizes, including the endemic *Macandrewia azorica* (Figure 8b). In such deep areas, when the rock displays a softer relief, the benthic community is dominated by the primnoids *Narella bellissima* and *Narella versluysi*, together with the white coral *Pleurocorallium johnsoni* and the laminate sponge cf. *Poecillastra compressa* (Figure 8c).

Shallower areas, between 300 and 500 m depth, host rich communities characterized by a wide variety of coral and sponge species. Especially relevant are the dense aggregations of a pink soft coral still to be identified to species level, observed in very large numbers along the small crevices of the rocks, mostly on the upper slopes (Figure 8d). Large colonies of the whip coral *Viminella flagellum*, *Callogorgia verticillata*, *Paragorgia johnsoni* and *Paracalyptrophora josephinae* are commonly observed on those areas, as well as on the summit. Some of the *Callogorgia* colonies identified reach some large sizes (Figure 8e), but they have not yet been observed forming dense patches similar to those found in other seamounts. Also very relevant is the size of some specimens of the giant sponge cf. *Characella pachastrelloides*, generally observed in association with the whip coral *Viminella flagellum* on some localized areas of the summit (Figure 8f). A few other sponge species appear alongside the large *Characella*, such as *Leiodermatium* spp. and *Macandrewia azorica.*

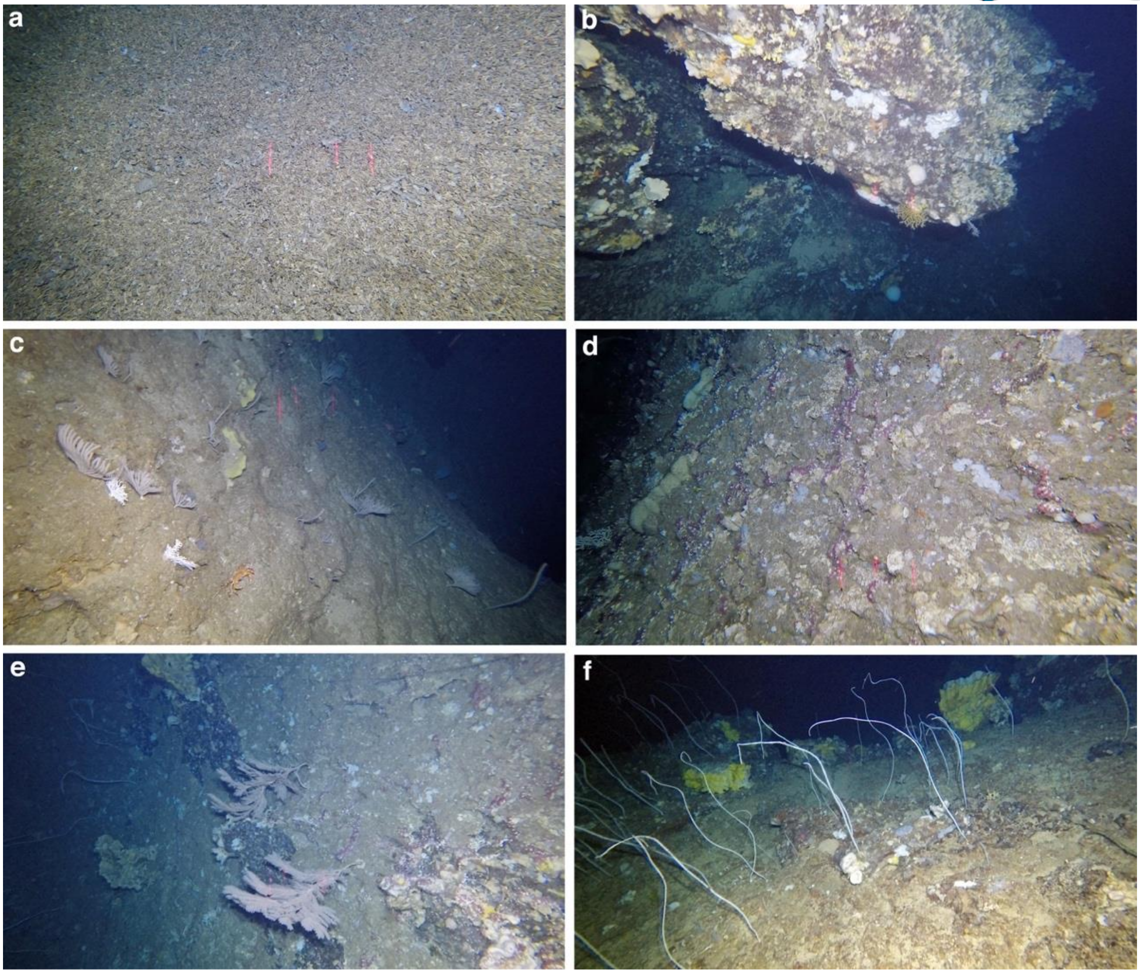

Figure 8. *Images showing some of the benthic communities that have been identified in A6 seamount. (a) Deposits of coral rubble over a soft bottom area. (b) Vertical cliffs and outcropping rocks colonized by a large variety of encrusting sponges. (c) Aggregation of the primnoid corals Narella bellissima and Narella versluysi together with the yellow sponge cf. Poecillastra compressa (d) Dense aggregation of the soft corals on hard grounds of the upper slope. (e) Large colonies of the octocoral Callogorgia verticilata within a dense aggregation of soft corals. (f) Area of high densities of the whip coral Viminella flagellum developing in association with the large porifera cf. Characella pachastrelloides. © Drift cam, IMAR/Okeanos UAç.*

2.4. Ferradura seamount

Depth range explored: 475 - 665 m. 7 dives.

The deepest areas of this seamount are characterized by large deposits of coral rubble, still of an unknown origin (Figure 9a). Such deposits are usually found in between patches of sand, where some specimens of the scleractinian *Flabellum* sp. are observed. When bare outcropping rocks appear, it is common to see the sea urchin cf. *Cidaris cidaris* together with the yellow cup coral *Leptopsammia formosa* (Figure 9b) and the black coral *Paranthipathes larix*. At those depths, however, the most usual community observed is that dominated by the primnoids *Narella bellissima* and *Narella versluysi*, with different accompanying species. In some cases, generally when bare rock dominates, some specimens of the black coral *Leiopathes expansa* and sea urchins of the genus cf. *Echinus* are common (Figure 9c). Other species are also very abundant, with the anthozoan *Pseudoanthomastus* cf. *agaricus* reaching some very high densities (Figure 9d).

At shallower depths, the *Narella* community transitions to that dominated by the gorgonian coral *Paragorgia johnsoni*, both in its red and white morphs. The accompanying fauna remains very similar to that of deeper areas, being very common the red coral *Pseudoanthomastus* cf. *agaricus* and the sponges cf. *Poecillastra compressa* and cf. *Petrosia crassa*. The shallowest areas explored host dense patches of the large gorgonian coral *Callogorgia verticillata*, together with the whip coral *Viminella flagellum* and the ubiquitous *Pseudoanthomastus* cf. *agaricus* (Figure 9f). In some areas, the large *Callogorgia* specimens disappear to leave monospecific patches of *Viminella flagellum*.

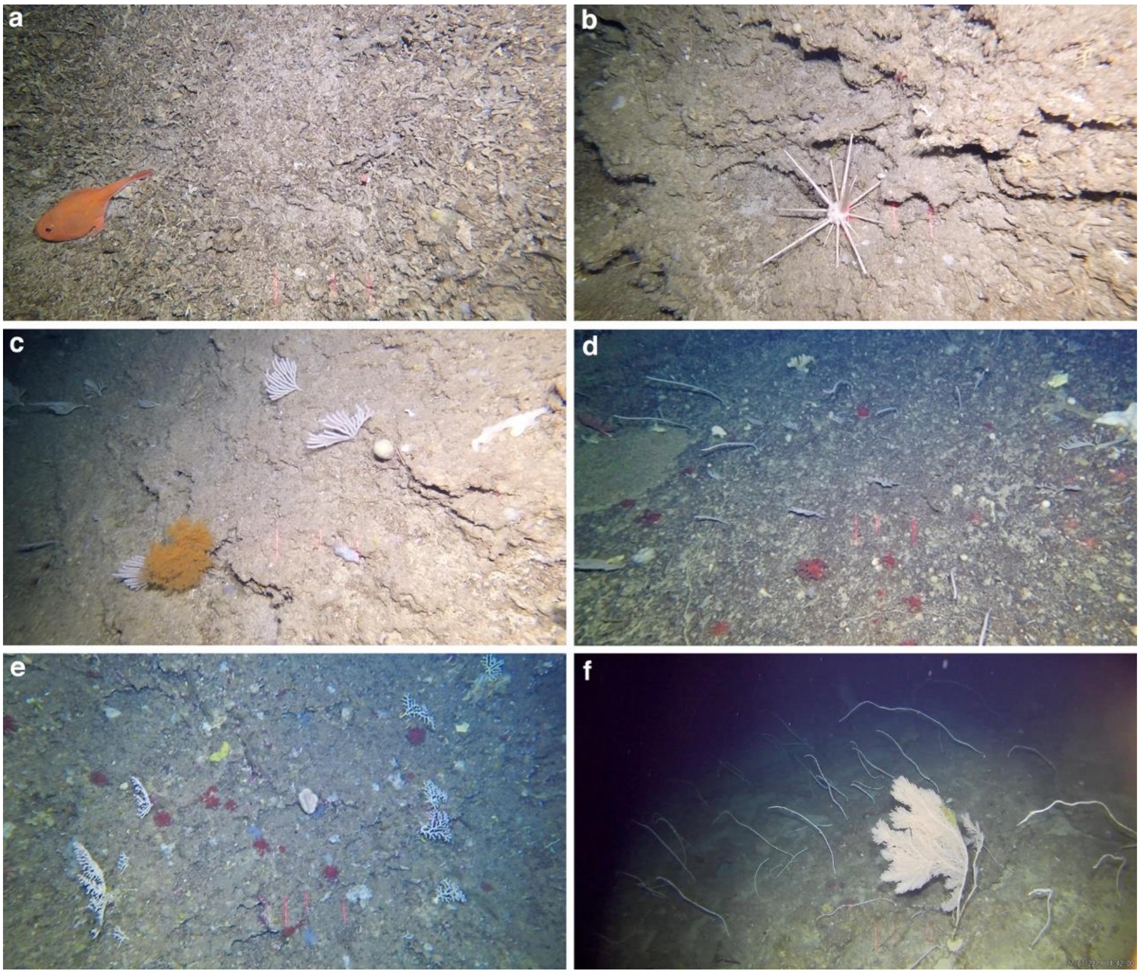

Figure 9. *Images showing some of the benthic communities that have been identified in Ferradura seamount. (a) Deposits of coral rubble over a soft bottom area with a fish of the genus Chaunax. (b) Bare outcropping rocks with the long-spine sea urchin Cidaris cidaris. (c) Aggregation of the primnoid corals Narella bellissima and Narella versluysi together with the black coral Leiopathes expansa. (d) Dense aggregation of the primnoid corals Narella bellissima and Narella versluysi together with the soft coral Pseudoanthomastus cf. agaricus on hard grounds. (e) Area of high densities of the bubblegum coral Paragorgia johnsoni developing in association with the soft coral Pseudoanthomastus cf. agaricus. (f) Large colonies of the octocoral Callogorgia verticilata within an aggregation of the whip coral Viminella flagellum. © Drift cam, IMAR/Okeanos UAç.*

2.5. Cavala seamount

Depth range explored: 335 - 675 m. 15 dives.

The deepest areas explored in Cavala seamount, at 600-700 m depth, are characterized by the presence of gravels and small volcanic rocks, with little fauna observed besides some scattered sea urchins of the species cf. *Cidaris cidaris* (Figure 10a). Certain areas with gravels also host some glass sponges of the species *Pheronema carpenteri*, together with the anthozoan *Pseudoanthomastus* cf. *agaricus* and the small glass sponge *Farrea occa* (Figure 10b), all of them always in low densities. At depths of 500 m, large boulders and outcropping rocks become more common, and are mostly colonized by the white gorgonian coral *Pleurocorallium johnsoni* (Figure 10c), with a diverse set of accompanying species, including the yellow sponge cf. *Poecillastra compressa*, the ubiquitous anthozoan *Pseudoanthomastus* cf. *agaricus* and some black coral species such as cf.

Elatopathes abietina and *Stichopathes* cf. *gravieri*. Some of the white coral colonies of this community may belong to the species *Paragorgia johnsoni,* with both species coexisting in the same habitat. It is very difficult to tell apart both species when they have the same size merely from video images. The density and size of the *Paragorgia johnsoni* colonies increases towards shallower depths (Figure 10d), while the composition and structure of the associated fauna is maintained adding to the list the whip coral *Viminella fagellum*. Also at those depths, the presence of vertical or very steep walls constitutes a change in the community composition, with a clear dominance of encrusting sponges, as well as some large individuals of the species *Macandrewia azorica* and *Petrosia crassa,* among others.

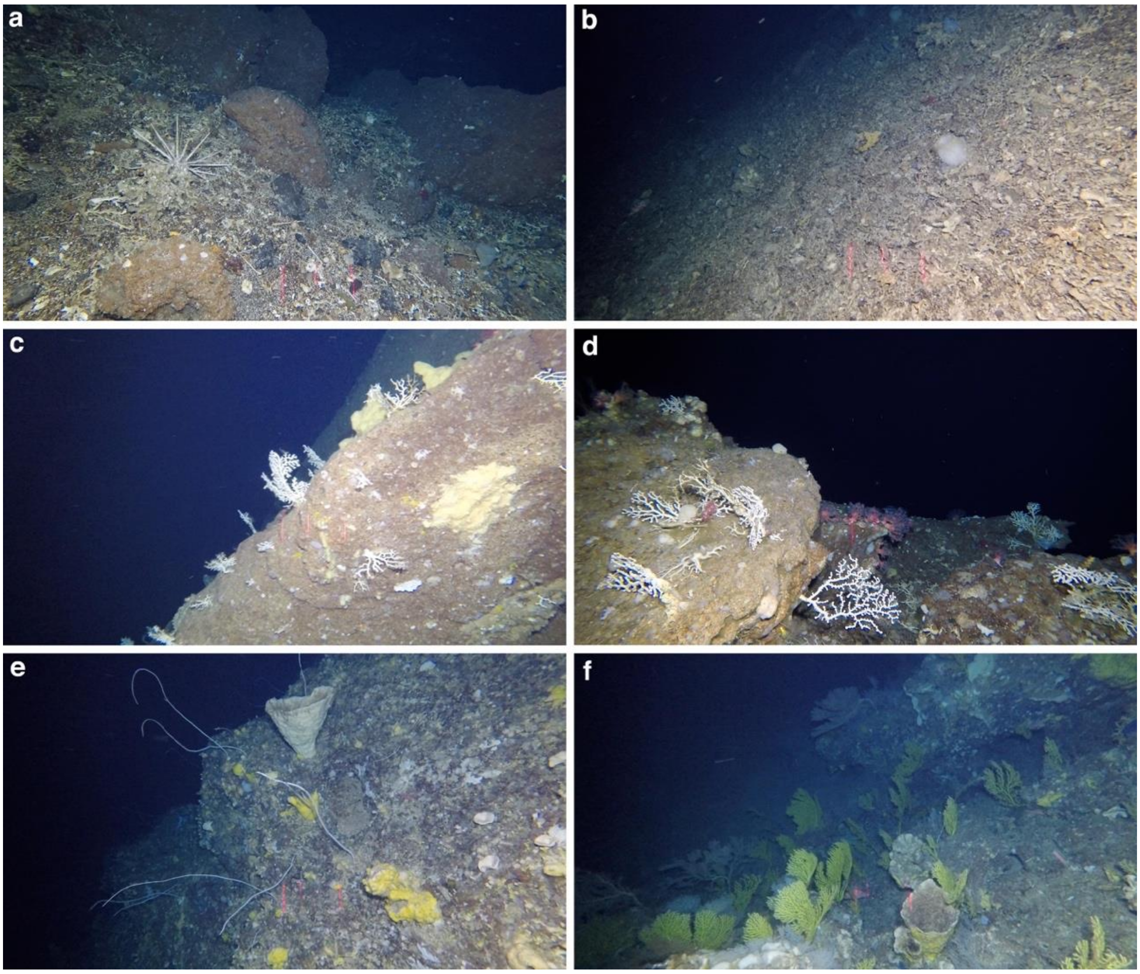

Figure 10. *Images showing some of the benthic communities that have been identified in Cavala seamount. (a) Gravels and small volcanic rocks with the long-spine sea urchin Cidaris cidaris. (b) Coral rubble with some specimens of the glass sponge Pheronema carpenteri. (c) Large boulder colonized by the white gorgonian Pleurocorallium johnsoni and the laminate sponge cf. Poecillastra compressa. (d) Area of high densities of the bubblegum coral Paragorgia johnsoni in association with soft corals, including Pseudoanthomastus cf. agaricus. (e) Large outcropping rock with the whip coral Viminella flagellum and some very large sponges of the species cf. Characella pachastrelloides. (f) Large densities of the yellow sea fan Dentomuricea aff. meteor in summit areas characterized by large boulders and outcropping rocks. © Drift cam, IMAR/Okeanos UAç.*

The benthic community drastically changes when reaching the shallowest sectors of the seamount, with a clear dominance of the whip coral *Viminella flagellum*, becoming the most common coral species of all (Figure 10e). It is observed in association with the large sponges cf. *Characella pachastrelloides* and cf. *Petrosia crassa* in areas colonized by a large number of encrusting sponges, while found in association in other points with the gorgonian corals *Acanthogogia* cf. *hirsuta*, *Dentomuricea* aff. *meteor* and *Callogorgia verticillata*, as well as very large colonies of *Paracalyptrophora josephinae*. An exceptionally dense aggregation of the yellow sea fan *Dentomuricea* aff. *meteor* was identified in the shallowest area of the summit, below 400 m depth (Figure 10f). The densities recorded for this species in Cavala seamount might represent some of the greatest encountered in the Azores region so far.

2.6. Beta seamount

Depth range explored: 540 - 745 m. 5 dives.

The deepest areas of Beta seamount explored until now are mainly characterized by very coarse gravels, mostly composed of coral rubble of an unknown origin. Such areas host very few organisms, including some crustaceans like *Chaceon affinis* (Figure 11a), and sparse corals of the species *Narella versluysi*. When the substrate becomes more consolidated, the density of the primnoids *Narella versluysi* and *Narella bellissima* starts to increase, as well as that of the anthozoan *Pseudoanthomastus* cf. *agaricus* and the glass sponge *Asconema* sp (Figure 11b). In this *Narella* community, a few deep-sea sharks of the species *Dalatias licha* have been observed gently swimming close to the seabed (Figure 11c).

In shallower depths, the community changes to a more complex and diverse association, in which a large number of species can be identified: the white gorgonian *Pleurocorallium johnsoni*, large porifera of the species *Characella pachastrelloides*, the yellow laminate sponge cf. *Poecillastra compressa*, a wide variety of encrusting sponges and a very abundant small plexauridae gorgonian coral, of an orange coloration, most likely to belong to the genus *Swiftia* (Figure 11d). Also on the slopes of the mound and within this community, but further up towards the summit, the bubblegum coral *Paragorgia johnsoni* in its red and white morphs starts to appear, with colonies reaching some of the largest sizes recorded for this species in the whole Azores region (Figure 11e). On the flat areas of the summit, a remarkable aggregation of the Rossellidae sponge *Asconema* sp. has also been registered, with patches of some very high densities (Figure 11f).

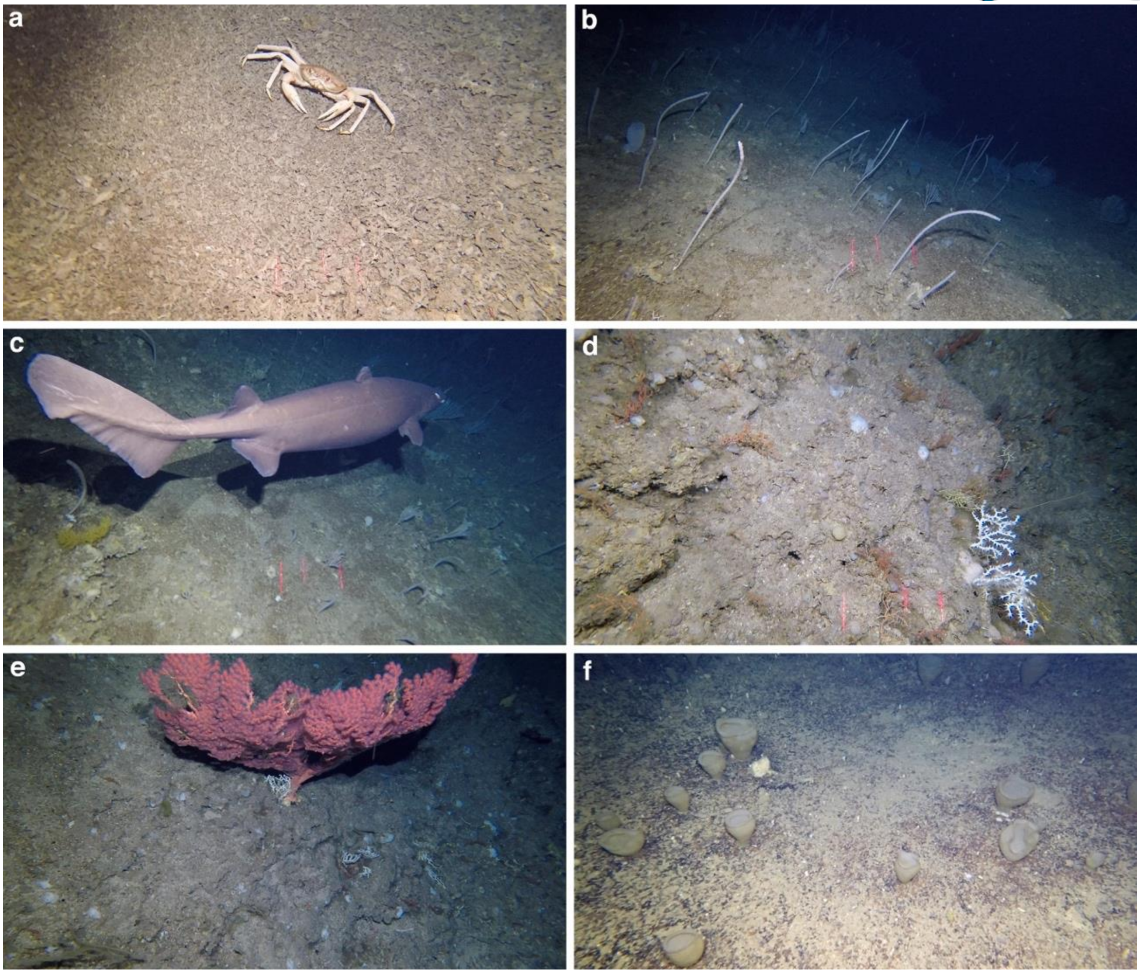

Figure 11. *Images showing some of the benthic communities that have been identified in Beta seamount. (a) Accumulations of coral rubble of an unknown origin. (b) Aggregation of the Primnoid corals Narella versluysi and Narella bellissima in the deepest areas explored. (c) A large deep-sea shark of the species Dalatias licha. (d) High densities of an orange Plexauridae most likely of the genus Swiftia, alongside some specimens of the white coral Pleurocorallium johnsoni. (e) One example of the large sizes that the corals Paragorgia johnsoni reach in the slopes of Beta seamount. (f) Aggregation of the sponge Asconema sp. © Drift cam, IMAR/Okeanos UAç.*

2.7. Picoto seamount

Depth range explored: 460 - 660 m. Number of dives: 5

The deepest part of Picoto seamount is characterized by clean slopping walls with small cnidarians, such as *Pleurocorallium johnsoni*, *Leptopsammia formosa* and *Pseudoanthomastus* cf. *agaricus*, as well as the yellow laminate sponge cf. *Poecillastra compressa* (Figure 12a). Some areas of coral rubble of an unknown origin exist between the rocky outcrops, with no visible fauna associated to them. In some sections, the color of the rock changes to a darker tonality, hosting a different community characterized by the presence of a wide variety of encrusting and erect sponges such as cf. *Petrosia crassa* and *Craniella longipilis* (Figure 12b), as well as several glass sponges. In shallower areas, the whip coral *Viminella flagellum* becomes the dominant coral species, forming some dense patches (Figure 12c). Interestingly, in between the *Viminella* colonies, some very large *Callogorgia verticillata* can be observed, generating very dense patches of some tens of meters in length (Figure 12d). These aggregations might host some of the largest *Callogorgia* colonies observed in the Azores region to date. Within this corals, very large specimens of the fishes *Conger conger* and *Polyprion americanus* can be observed, together with some deep-sea sharks.

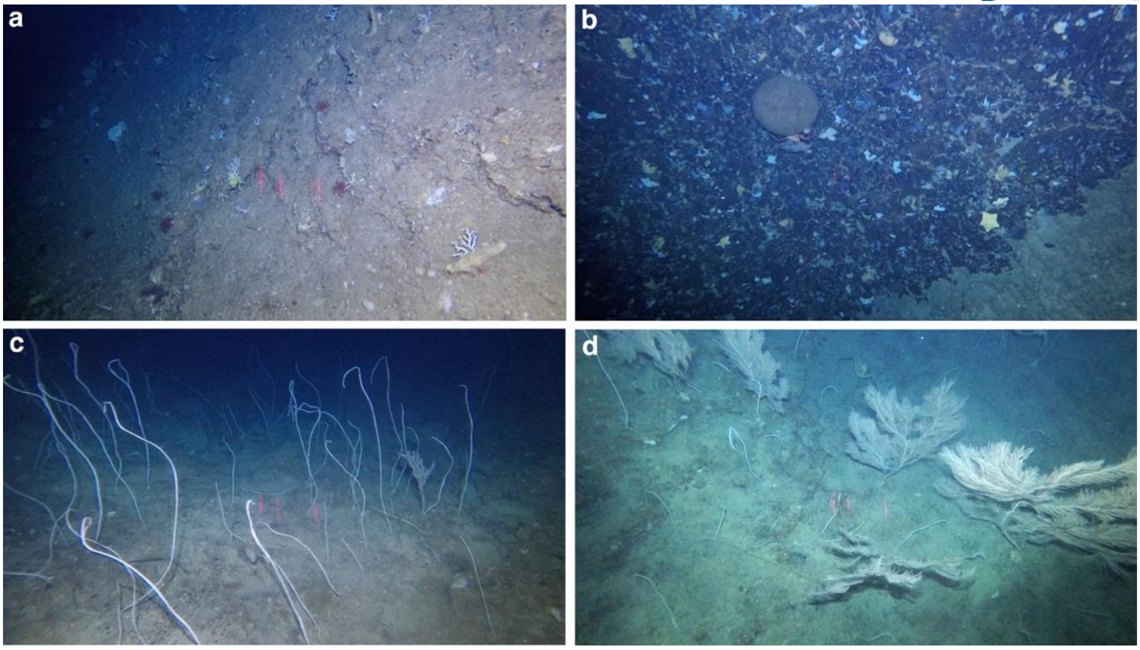

Figure 12. Images showing some of the benthic communities that have been identified in Picoto seamount. (a) Clear outcropping rocks with Pleurocorallium johnsoni and Pseudoanthomastus cf. agaricus. (b) Aspect of the black rocky outcrops colonized by encrusting sponges, together with some other larger species such as Craniella longipilis. (c) Viminella flagellum aggregation on the shallowest areas explored. (d) Some of the very large colonies of Callogorgia verticillata observed in this seamount. © Drift cam, IMAR/Okeanos UAç.

2.8. Alfa seamount

Depth range explored: 480 - 745 m. 7 dives.

Not many benthic communities have been identified in Alfa seamount to date, and the densities of the main structuring species observed tend to be low in general. The highest diversities are found in areas where the mother rock has a darker tonality, where a wide variety of sponge species live attached to, with a clear dominance of encrusting species of different colors. Between the encrusting sponges, some other large Porifera can be identified, including *Craniella longipilis* and cf. *Characella pachastrelloides*, as well as the ubiquitous small soft coral *Pseudoanthomastus* cf. *agaricus* (Figure 13a). The black rock also hosts the common association between the white coral *Pleurocorallium johnsoni* and the laminate sponge cf. *Poecillastra compressa* (Figure 13b), although boths species are generally found in low abundances. When the rock has a clearer tonality, the dominance of sponge species shifts to a community dominated by the whip coral *Viminella flagellum* and the small anthozoan *Pseudoanthomastus* cf. *agaricus*, always in relatively low densities (Figure 13c). Among all the video footage obtained, the presence of soft bottom areas of sand and gravel was low, and partially covered by deposits of coral rubble of an unknown origin. In opposition to other seamounts of the MAR, not many large fishes have been reported, besides the occasional deep-sea shark of the species *Hexanchus griseus*. Quite a few abandoned fishing lines were registered in this seamount, some of which fully covered in small fauna indicating that these gears might have been there for quite a long time (Figure 13d).

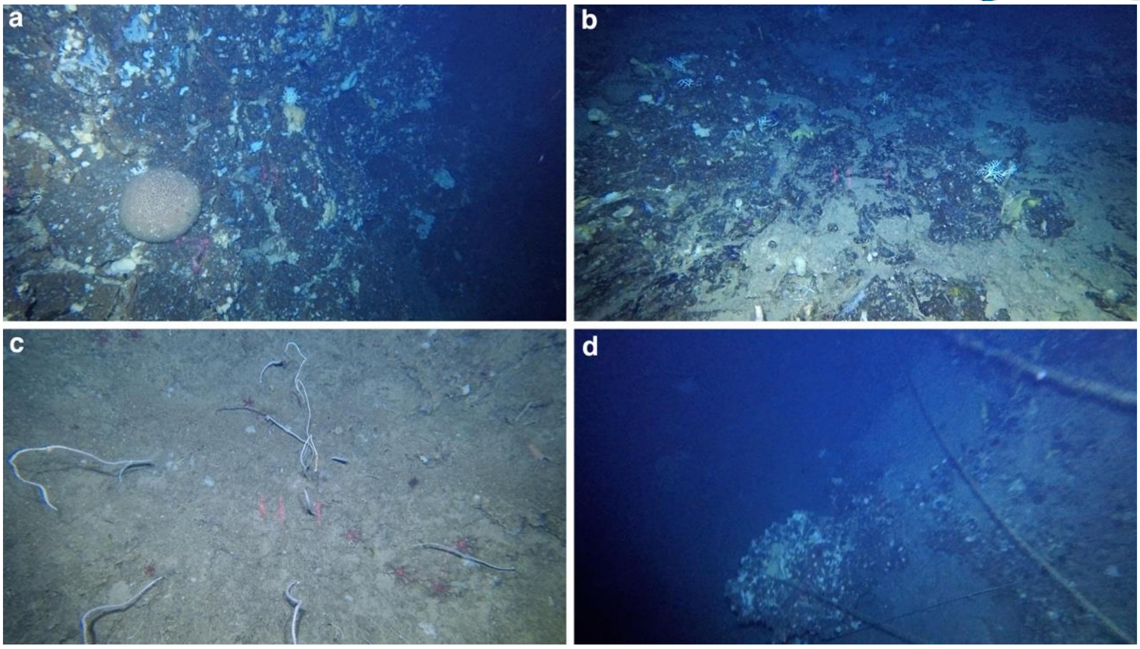

Figure 13. *Images showing some of the benthic communities that have been identified in Alfa seamount. (a) Dark rock colonized by a wide variety of sponge species, with a large Craniella longipilis in the lower part of the image. (b) Flat area of dark rock with the white coral Pleurocorallium johnsoni and the laminate yellow sponge Poecillastra compressa. (c) The whip coral Viminella flagellum in association with the red anthozoan Pseudoanthomastus cf. agaricus. (d) Some of the large cables abandoned over the seabed. © Drift cam, IMAR/Okeanos UAç.*

2.9. Voador seamount

Depth range explored: 250 - 580 m. 14 dives.

Most of the slope and summit areas explored in Voador seamount correspond to rocky outcrops and large boulders, with very few mud/sand patches overall. In the rocky areas of the slopes, the megabenthic community is generally characterized by the presence of different species of sponges, especially when the rock displays a dark coloration (Figure 14a). Encrusting sponges are commonly observed throughout the hard substrates, accompanied by several large sponges of the species cf. *Macandrewia azorica*, *Petrosia* cf. *crassa*, cf. *Neophrisospongia nolitangere*, *Craniella longipilis*, *Leiodermatium* spp. and cf. *Characella pachastrelloides*. Some scattered colonies of the whip coral *Viminella flagellum* appear in this sponge community, but never forming dense patches. This Porifera-dominated species composition has been observed in many sectors of Voador seamount, especially in the deepest areas explored, although it also extends into the summit. The size of some cf. *Characella pachastrelloides* found in this seamount is remarkable (Figure 14b), and have been observed serving as substrate to other life forms, such as anemones and small hydrozoans, and as refuge to small fish species, such as juveniles of *Helicolenus dactylopterus*. Interestingly, a few specimens of the lollipop sponge *Stylocordyla pellita* have also been identified within this community, although always as solitary individuals and never generating dense patches, in opposition to what has been observed in other seamounts.

Very dense aggregations of *Candidella imbricata* appear in shallower areas, mainly developing over rocky outcrops and large boulders (Figure 14c). A wide variety of small sponges and other gorgonian species can be associated to this community, in which the yellow morph of the whip coral *Viminella flagellum* and the primnoid *Callogorgia verticillata* stand out due to the density and size of the colonies. Some broken branches of the latter species have been reported, indicating the potentially negative effect that fishing activities may have over this community. Some large *Callogorgia verticillata* colonies have also been observed generating monospecific patches on the smooth slopes of this seamount, generally with very little fauna associated to them (Figure 14d). Another very interesting community observed in Voador seamount corresponds to that formed by the association between the large primnoid *Paracalyptrophora josephinae* and a hydroid species, whose identification still remains to be determined (Figure 14e). The density of *Paracalyptrophora josephinae* in this seamount is one of the highest ever recorded in the Azores, since this primnoid is usually observed as an accompanying species in other communities, and rarely seen forming aggregations. Some large six-gill sharks (*Hexanchus griseus*) have been reported from the slopes of this seamount too (Figure 14f). Over sedimentary areas, the number of invertebrate species identified is very low, and limited to some echinoderms, such as sea urchins of the genus cf. *Echinus*. In the sandy areas, some gravel deposits have been observed, in some cases occupying a very large part of the seabed. Most of these deposits seem to have a lithogenic origin, although a small percentage corresponds to small pieces of coral rubble.

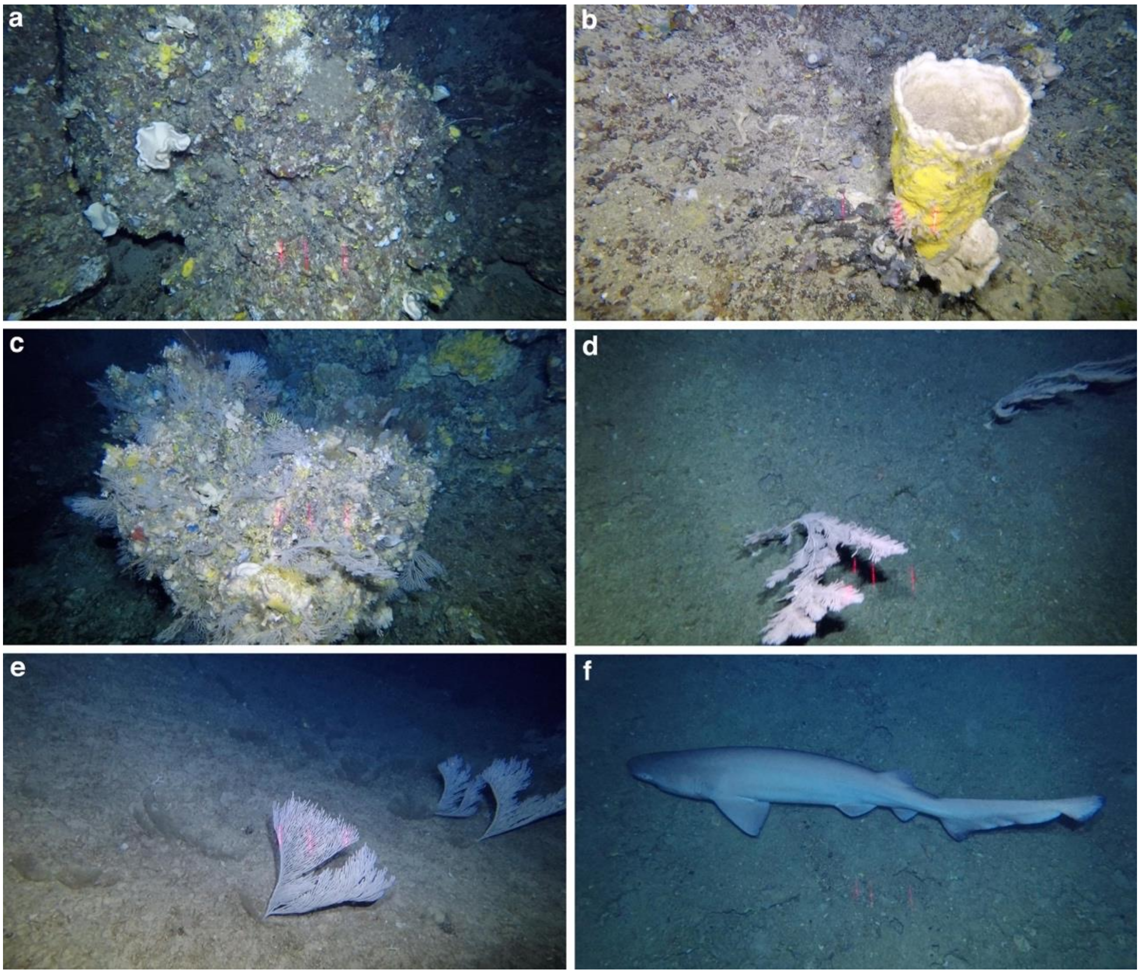

Figure 14. *Images showing some of the benthic communities that have been identified in Voador seamount. (a) Some of the various species of Porifera observed on large rocky outcrops and vertical walls. (b) One of the many giant cf. Characella pachastrelloides observed on the slopes of this seamount. (c) A large boulder completely covered in sea fans of the species Candidella imbricata. (d) Large colonies of the species Callogorgia verticillata on the smooth rock of the slope. (e) Association between the coral Paracalyptrophora josephinae and a large hydrozoan. (f) A six-gill shark Hexanchus griseus. © Drift cam, IMAR/Okeanos UAç.*

2.10. Monte Alto seamount

Depth range explored: 385 - 555 m. 6 dives.

In Monte Alto, the percentage of soft substrates that can be found on the summit is very large. Most of the areas explored until now correspond to extensive sandy areas (Figure 15a), some of which characterized by the presence of well-formed ripples, most likely caused by the action of bottom currents. In this homogenous habitat, the number of species reported is rather low, with two species standing out above the rest: the solitary scleractinian coral *Flabellum* sp. and a yellow/orange sea star of the Goniasteridae family. Some boulders of black rock can sometimes be observed scattered along the sand, and in most cases colonized by large colonies of the whip coral *Viminella flagellum*, generally in low densities (Figure 15b). In contrast, when the substrate becomes coarser and the rock outcrops, a sharp increase in the number of invertebrate species can be observed. In most cases, the most abundant group is Porifera, with a clear dominance of small encrusting and digitate sponges of various colors (Figure 15c). Quite an extensive list of species has already been reported on these hard substrates, and include cf. *Neophrissospongia nolitangere*, *Leiodermatium lynceus*, cf. *Petrosia crassa* and *Macandrewia azorica,* as well as the very large *Craniella longipilis* and cf. *Characella pachastrelloides.* Less common is the presence of structuring corals. In one sector where rocky outcrops are predominant, some very large *Callogorgia verticillata* have been reported, with some patches of relatively high densities (Figure 15d), although those sightings are rare in Monte Alto seamount.

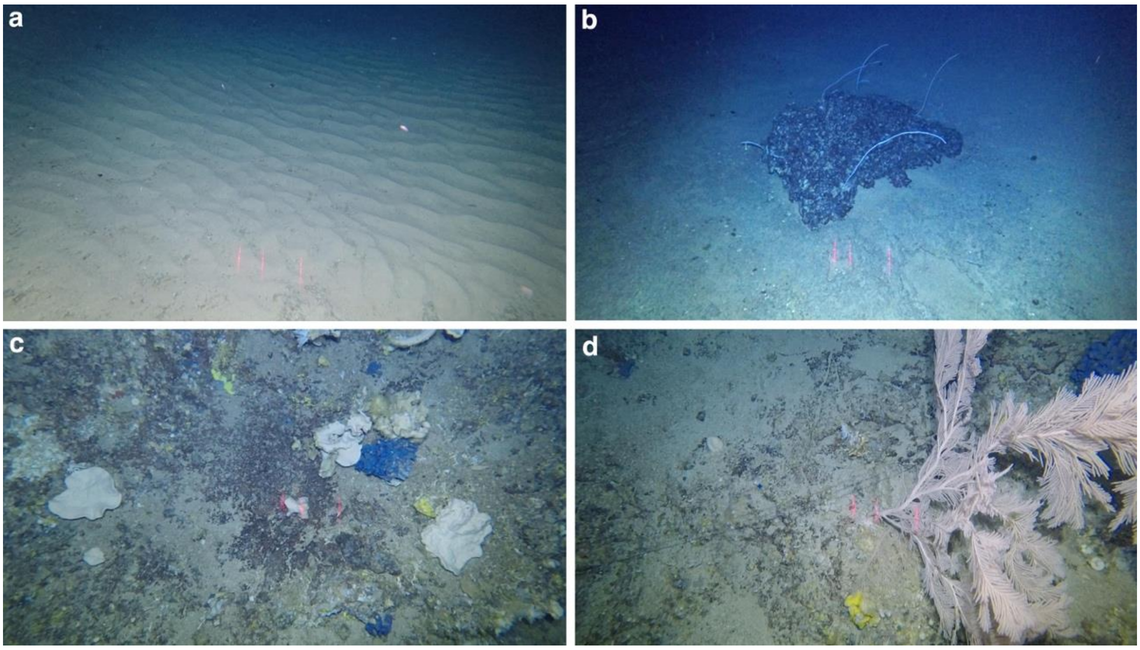

Figure 15. *Images showing some of the benthic communities that have been identified in Monte Alto seamount. (a) Ripples in sandy areas of the summit. (b) Some large whip corals of the species Viminella flagellum in one of the scattered boulders that can be observed in the sandy areas. (c) Aspect of the sponge aggregations in hard grounds. (d) A well-preserved colony of the primnoid coral Callogorgia verticillata. © Drift cam, IMAR/Okeanos UAç.*

2.11. A3 seamount

Depth range explored: 450 - 550 m. 6 dives.

The most common species observed in A3 seamount is the whip coral *Viminella flagellum*, which appears in many of the areas explored. The aggregations of *Viminella flagellum* are generally monospecific (Figure 16a-b), with not many other corals observed as accompanying species. Some small fauna has been identified within those patches, and includes the black corals *Stichopathes* cf. *gravieri* and *Paranthipathes hirondelle*, one purple anthozoan yet to be identified and a sea star of the Goniasteridae family, as well as some small and encrusting sponges and gorgonians impossible to identify from the recorded images. Sporadically, a very large specimen of the sponge species cf. *Characella pachastrelloides* appears within this community (Figure 16c). Some fishes have been spotted swimming between the coral colonies, mostly belonging to the Gadidae family. When the rock appears with a darker coloration, the community shifts to one characterized by a large number of sponge species, mainly small and encrusting, but also with a few larger organisms: *Craniella longipilis*, *Petrosia* cf. *crassa* and cf. *Characella pachastrelloides* (Figure 16d-e). Also noticeable is the presence of coral rubble, either in between the rocks or on top of sandy and gravelly areas (Figure 16f).

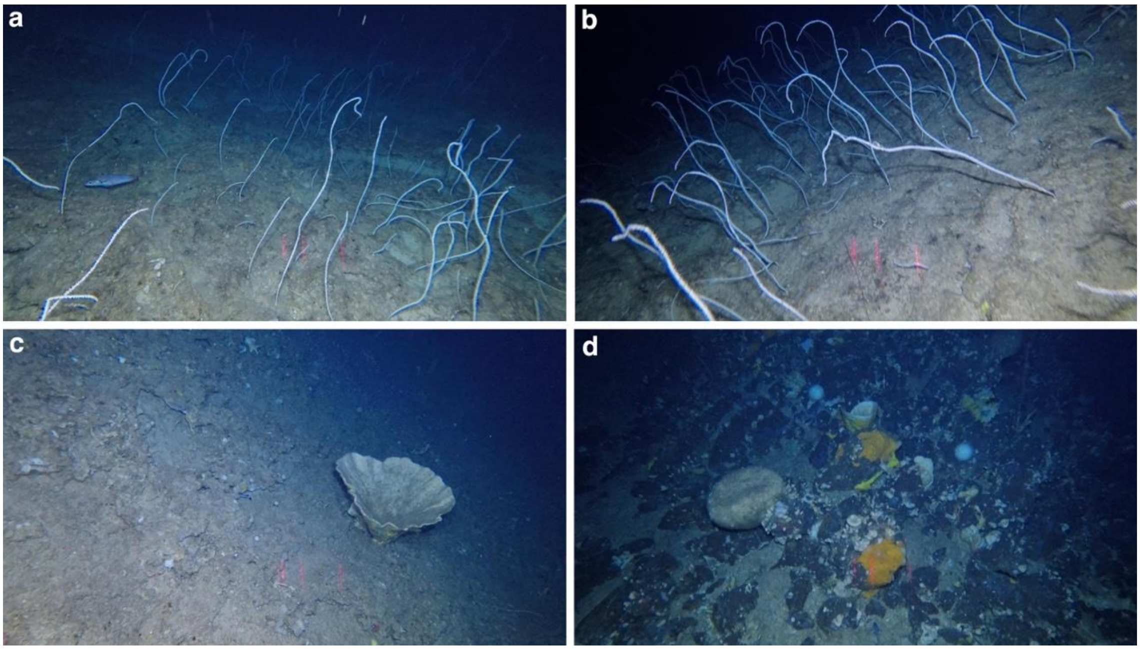

Figure 16. *Images showing some of the benthic communities that have been identified in A3 seamount. (a-b) Aggregation of the whip coral Viminella flagellum in relatively high densities. (c) One very large and solitary cf. Characella pachastrelloides found on one of the slopes, close to the summit. (d-e) Sponge community found on dark rocks, with a wide variety of species of diverse colors. © Drift cam, IMAR/Okeanos UAç.*

2.12. Sarda seamount

Depth range explored: 430 - 1150 m. 4 dives.

Sarda seamount displays a very clear bathymetric zonation in terms of species composition, with two very contrasting sectors. The western ridge, which stretches for more than 70 km, presents sharper slopes and cliffs, and it is mainly characterized by a wide diversity of sponge species. Its summit however, hosts dense aggregations of the whip coral *Viminella flagellum*. Conversely, the smaller seamount located on the eastern side is mainly dominated by several structuring octocoral species, which are clearly segregated along the bathymetric gradient.

The deepest areas of the western ridge, below 1000 m depth, are composed of a mixture of mud, sand and gravels, and two main aggregations have been observed: the glass sponge *Hyalonema* sp. and the benthic foraminifera cf. *Syringammina fragilissima*. On the deepest part of the slope, where rocks began to outcrop, aggregations the gorgonian coral *Candidella imbricata* (Figure 17a) and the large glass sponge *Pheronema carpenteri* are commonly observed (Figure 17b). Moving towards shallower areas, on the middle part of the slope, a wide variety of large sponges can be observed, in which to include cf. *Petrosia crassa*, cf. *Neophrissospongia nolitangere*, *Leiodermatium* spp. and cf. *Charasella pachastreloides* (Figure 17c). In the summit area, the whip coral *Viminella flagellum* is by far the most abundant and conspicuous species of all, reaching some very high densities in some sectors. This gorgonian coral seldom appears forming monospecific patches, and it is generally accompanied by a wide variety of species, in which to include the glass sponge *Asconema* sp., the sea fan *Acanthogorgia* sp., the yellow cup coral *Leptopsammia formosa* and large colonies of the primnoid *Callogorgia verticillata*. A few lithistid sponges are generally observed accompanying the dense patches of *Viminella flagellum*, including cf. *Petrosia crassa*, *Macandrewia azorica*, cf. *Neophrissospongia nolitangere* and cf. *Charasella pachastreloides*, among others.

The seamount on the northeastern displays a very different composition regarding its benthic megafauna, with coral-dominated communities in opposition to the sponge-dominated assemblages of the western slopes. The deepest part of the mound is characterized by 4 different cold-water coral species, including *Narella bellissima* and *Narella versluysi*, the large primnoid *Callogorgia verticillata* and the yellow sea fan *Acanthogorgia* sp., in all cases accompanied by the sponge cf. *Poecillastra compressa* (Figure 17d). In shallower areas, an aggregation of large colonies of the coral *Paragorgia johnsoni* can be observed, surrounded by a large number of the small scleractinian *Leptopsammia formosa* (Figure 17e). Towards the summit, the number of sponge species increases, to finally shift to a *Viminella flagellum* community, found in association with not only sponges such as *Leiodermatium* spp. and *Neophrissospongia nolitangere*, but also a large number of the sea fans *Acanthogorgia* sp. and *Callogorgia verticillata* (Figure 17f).

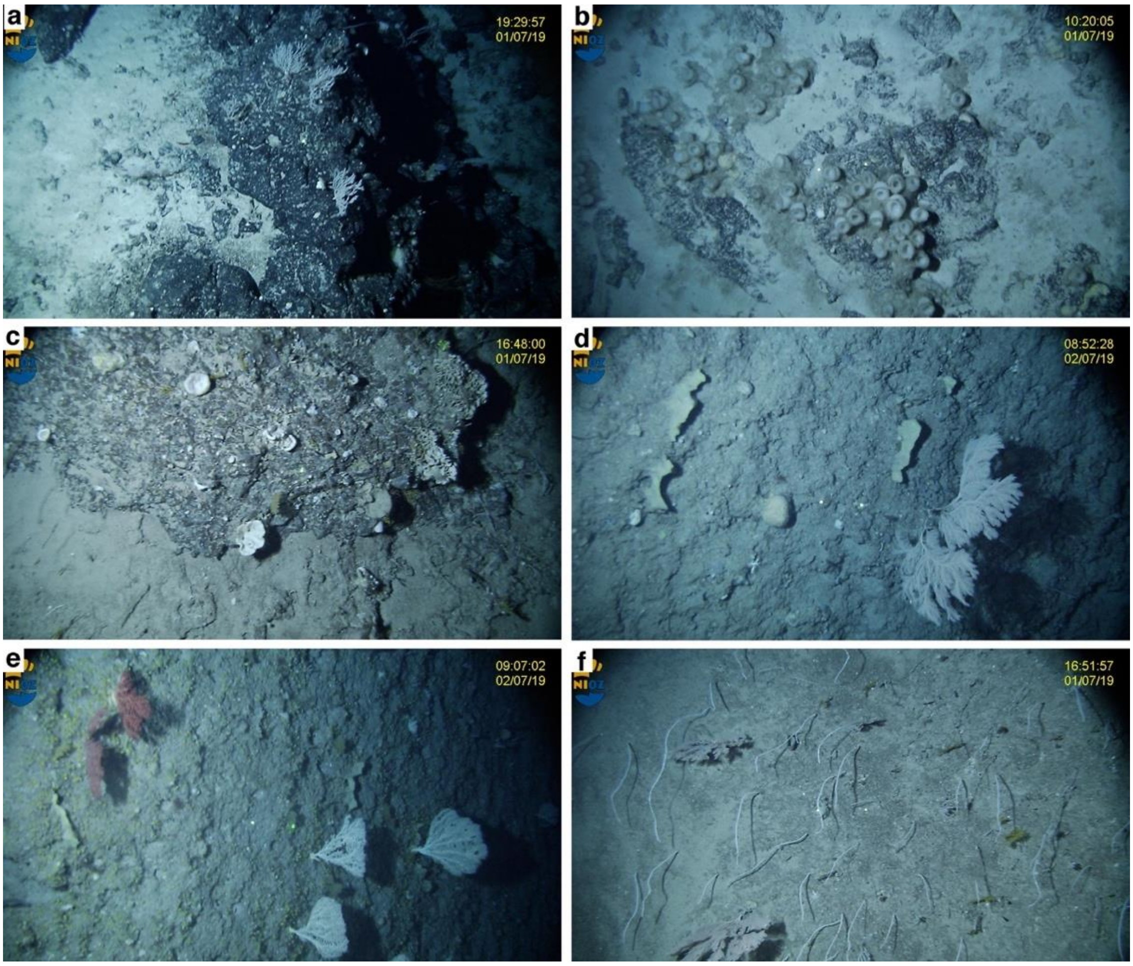

Figure 17. *Images showing some of the benthic communities that have been identified in Sarda seamount. (a). Colonies of the coral Candidella imbricata on rocky outcrops below 1000 m depth (b) Aggregation of the hexactinellid sponge Pheronema carpenteri. (c) Some of the sponge species found on the slopes of the western ridge. (d) Callogorgia verticillata with cf. Poecillastra compressa on the slope of the eastern feature. (e) Some of the large Paragorgia colonies observed oin the eastern feature. (f) Aspect of the summit of Sarda seamount, characterized by high densities of the whip coral Viminella flagellum. © Hopper tow-cam, NIOZ.*

2.13. Cavalo seamount

Depth range explored: 600 - 700 m. 1 dive.

Cavalo seamount is one of the features located furthest away from land, at a distance of more than 300 km from Faial island Although only one dive has been performed in Cavalo and covering a small depth range, the benthic communities observed in this seamount are very rich and diverse. Most hard substrates of the deepest areas explored are dominated by the primnoid species *Narella versluysi* and *Narella bellissima*, both found in rather high densities (especially the former, Figure 18a-b). The images recorded in Cavalo possibly represent the largest area of high densities of these species ever observed in the Azores region until now. This community is extremely diverse, with these two corals associated to a wide range of other species, including several species of sponges (e.g. *Haliclona magna*, cf. *Poecillastra compressa*) as well as other large corals, including *Paragorgia johnsoni*, *Pleuricorallium johnsoni* and *Callogorgia verticillata*. The anthozoan *Pseudoanthomastus* cf. *agaricus* and the sea urchins cf. *Cidaris cidaris* and cf. *Echinus* sp. are also commonly observed along the slope. Areas of the upper slope close to the summit host some very large colonies of the gorgonian coral *Paragorgia johnsoni* (Figure 18c), which appears with a few laminate sponges of the species cf. *Pachastrella monilifera*, not commonly observed in such densities (Figure 18d). When the rock acquires a darker tonality, a great change in species composition can be observed, transitioning to a sponge-dominated community that includes cf. *Petrosia crassa* and *Craniella longipilis,* as well as many encrusting and small-sized sponges of various colours (Figure 18e). In the shallowest part of the summit, the community is dominated by the yellow gorgonian *Acanthogorgia* sp. and very large colonies of the gorgonian species *Callogorgia verticillata* (Figure 18f), together with many other accompanying species, including large numbers of the small *Swiftia* sp.

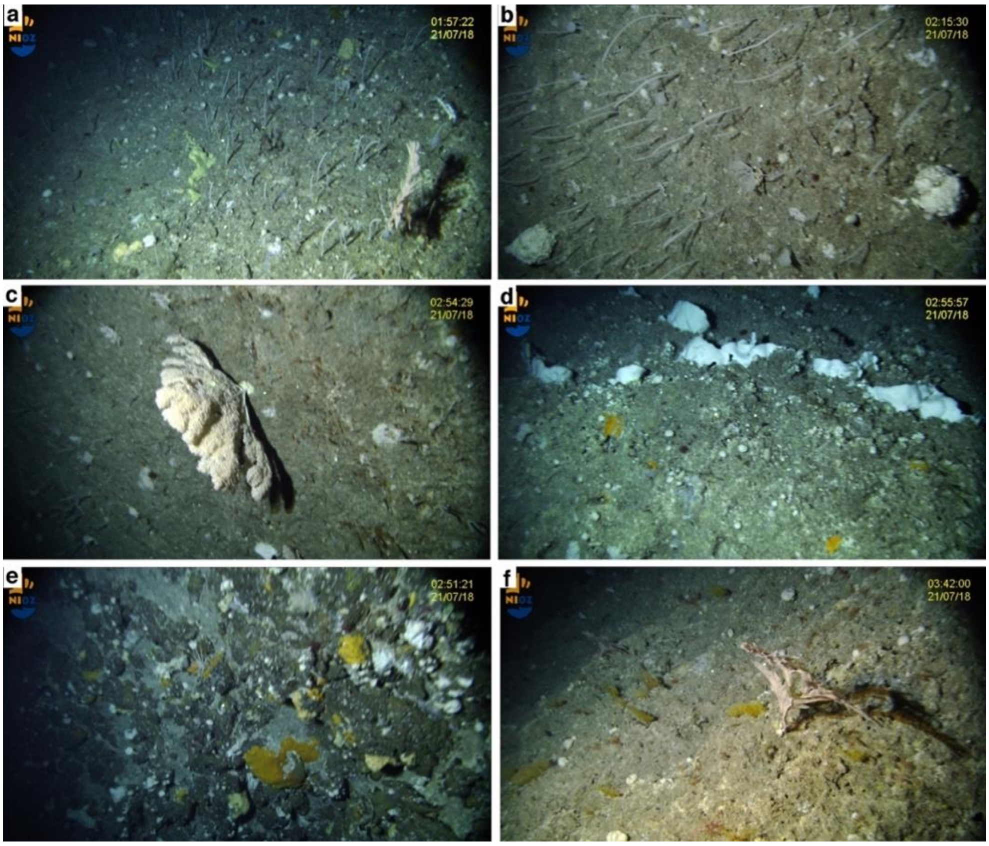

Figure 18. *Images showing some of the benthic communities that have been identified in Cavalo seamount. (a-b) Dense patches of the primnoid Narella versluysi on the hard substrates of the slope. (c) Large colony of the gorgonian coral Paragorgia johnsoni. (d) Laminate sponges of the species cf. Pachastrella monilifera. (e) Aggregation of sponges on sections of the slope where the rock had a darker coloration. (f) Aspect of the summit, with dense aggregations of the yellow sea fan Acanthogorgia sp. with a large colony of Callogorgia verticillata. © Hopper tow-cam, NIOZ.*

3. Central group

The Central group encompasses the islands of Faial, Pico, São Jorge, Graciosa and Terceira. In this area, the number of offshore features is limited to only a few seamounts and most deep-sea areas explored correspond to the slopes around the islands (Figure 19). Until today, 4 seamounts have been evaluated using underwater images: Condor, Baixo de São Mateus, São Jorge de Fora and Dom João de Castro. The remaining areas correspond to geomorphological structures around the islands, mostly slopes but also small seamount structures (Capelinhos and SE Pico). The extension of each geomorphological feature is shown in Figure 20.

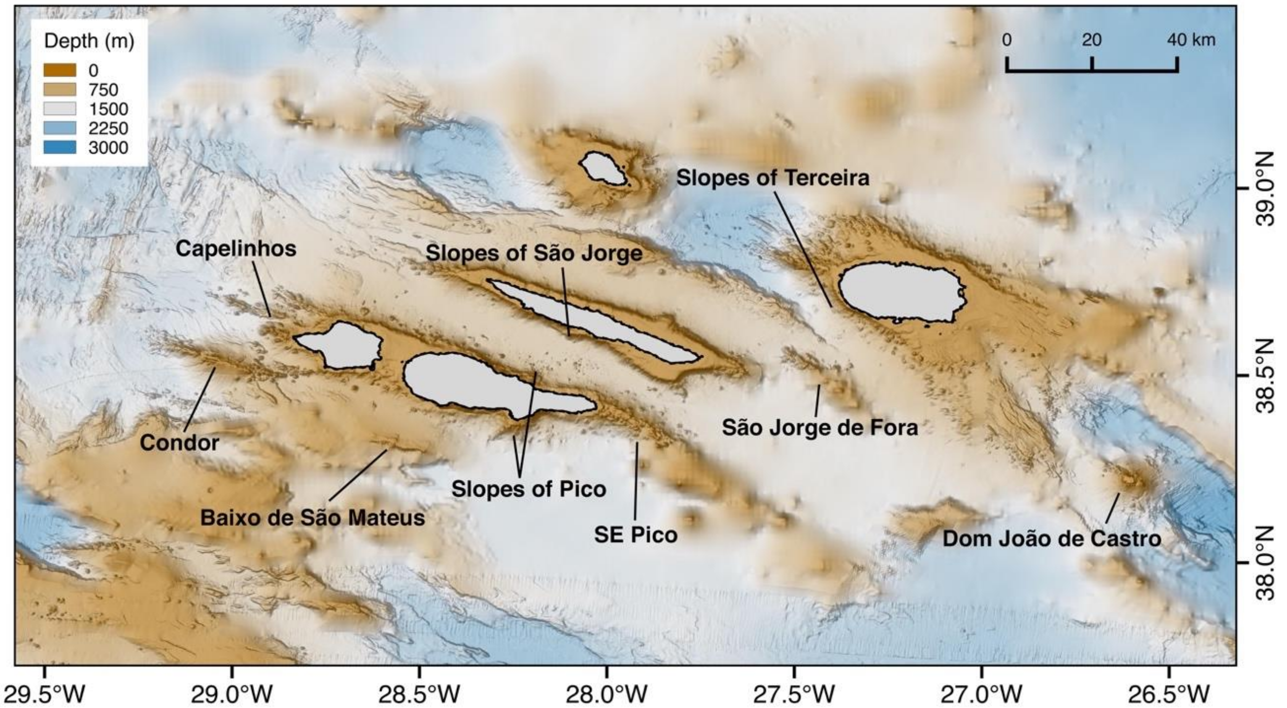

Figure 19. *Location of the different features explored on the islands of the Central group during the past 5 years.*

The underwater features of the central group were visited during 6 different oceanographic cruises in the summers of 2016, 2018 and 2019 on board of the NRP Gago Coutinho, R/V Pelagia, and N/I Arquipélago, as well as two dives with the submersible LULA as part of the Blue Azores program. In total, more than 50 underwater dives have been performed in these areas until now, with an asymmetric sampling effort, being the Capelinhos and the seamounts south-east of Pico where most of the dives have taken place. The depth range explored in this sector is larger than that of the Mid-Atlantic ridge, with 4 features explored below 1000 m depth. 35 dives (67% of the total) have been carried out with the drift-cam system developed at IMAR, used to explore 3 features: Capelinhos, the seamounts SE of Pico and Dom João de Castro. In these areas, the depth range evaluated stretches from very shallow locations (e.g. 100 m in Capelinhos) to around 500-600 m depth, almost at the base of those features. The ROV Luso has been employed to explore the slopes of Pico and São Jorge, with most dives starting below 1000 m and covering all the slope until depths of 500 m in Pico and 300 in São Jorge, providing a detailed characterization of the zonation patterns that occur within these features. The Hopper system has been used to explore the seamounts of Condor and Dom João de Castro, covering the whole depth range between the base of the seamount and the shallowest part of the summit, also giving insights about the zonation patterns that occur along the slopes of both features. Although only 4 dives have been performed in each of these seamounts, the lengths of those dives were extensive and the area explored very large.

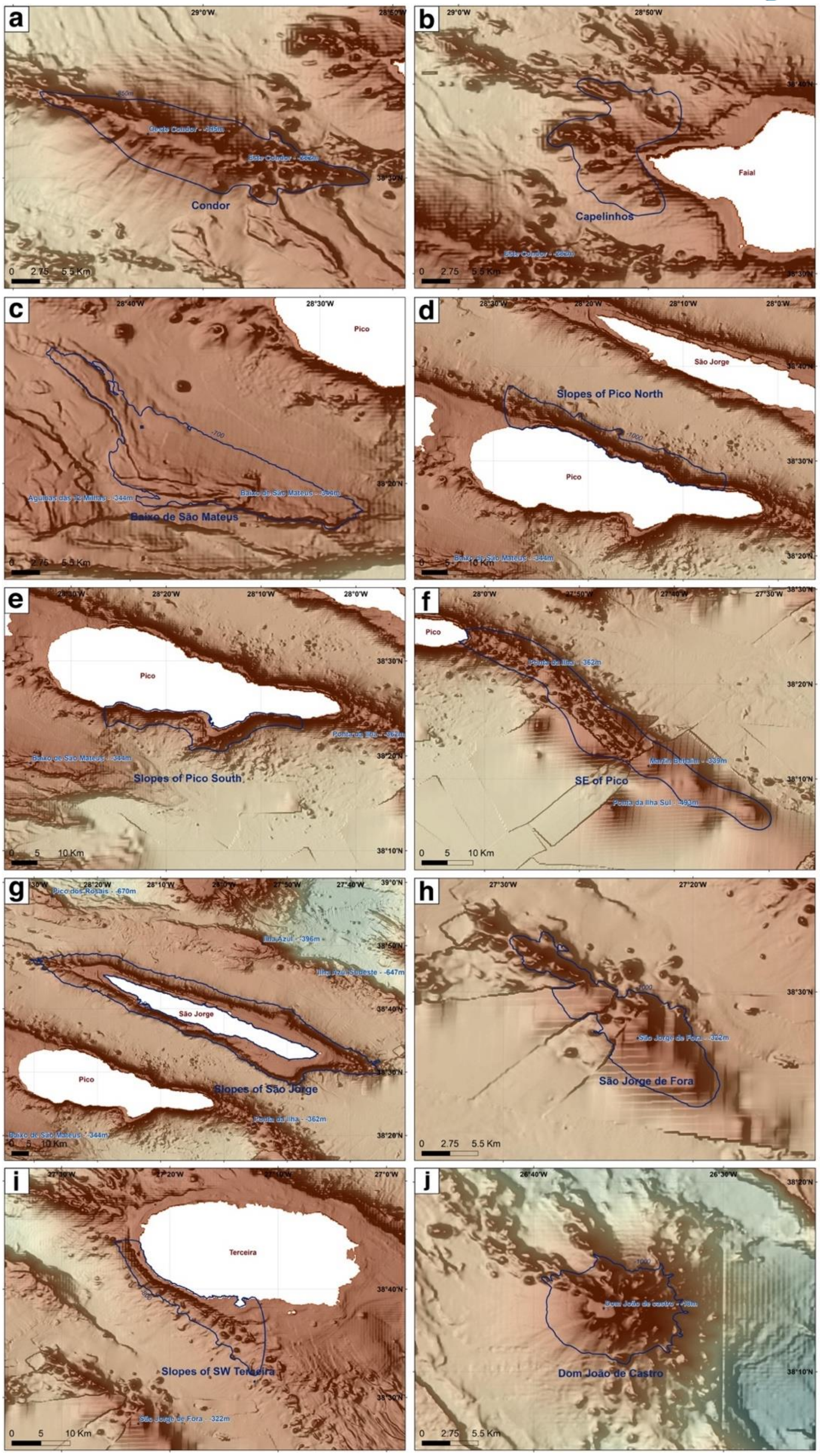

Figure 20. *Extension of each geomorphological feature evaluated in the central group (black lines). (a) Condor seamount. (b) Capelinhos. (e) Baixo de São Mateus. (d) Slopes north of Pico island. (e) Slopes south of Pico island. (f) Seamounts southeast of Pico island. (g) Slopes of São Jorge island. (h) São Jorge de Fora seamount. (i) Slopes of Terceira island. (j) Dom João de Castro seamount.*

Table 2. *Number of dives and platform used to explore each of the seamounts/slopes of the Central group. Depth indicates the shallowest and deepest points reached across all dives in each feature. Features are ordered following a longitudinal gradient, from west to east.*

Seamount/feature	Area (km^2)	Expedition	Year	Platform	Dives	Depth (m)
Condor	111	Midas	2016	Hopper	4	195 - 1065
Capelinhos	71	MapGES 2	2019	Drift-cam	18	100 - 650
Baixo de São Mateus	123	BlueAzores	2019	Lula 1000	2	500 - 1000
Slopes of Pico	157 (N)	BlueAzores	2018	Luso ROV	1	500 - 1100
	113 (S)	BlueAzores	2018	Luso ROV	2	500 - 1100
SE of Pico	351	MapGES 2	2019	Drift-cam	13	220 - 535
Slopes of São Jorge	762	BlueAzores	2018	Luso ROV	1	290 - 655
São Jorge de Fora	91	Terceira19	2019	Hopper	4	500 - 1300
Slopes of Terceira	125	Nico 12	2018	Hopper	3	500 - 830
Dom João de Castro	78	MapGES 1	2018	Drift-cam	4	220 - 475

3.1. Condor seamount

Depth range explored: 195 - 1065 m. 4 dives.

Condor is an elongated volcanic seamount located 17 km southwest of Faial Island. Its ridge extends NW-SE for 39 km, with its shallowest point on its flat summit at 185 m depth and its flanks extending with gentle slopes down to 2000 m depth. Regarding its deep-sea fauna, Condor shows a very clear zonation pattern strongly linked to depth, with the composition of the communities located on the summit displaying significant differences from those found on the seamount flanks. Coral gardens formed by the octocorals *Viminella flagellum*, *Dentomuricea* aff. *meteor* and *Callogorgia verticillata* (Figure 21a-b-c), together with the large hydrozoan cf. *Lytocarpia myriophyllum* dominate the summit of Condor. The three gorgonian species are found both in consolidated and unconsolidated substrates, with the dominance of one species over the others changing throughout the summit. Also at the summit, particularly on the hard substrates of the eastern edge, a dense aggregation of the hexactinellid sponge *Asconema* sp. has been found (Figure 21d) A small area of the summit also holds a patch of the scleractinian coral genus *Eguchipsammia*, composed mainly of coral rubble with a few living colonies over an area of 100 meters in length (Figure 21e).

The flanks of the seamount are characterized by a greater proportion of unconsolidated substrates compared to the summit, with sandy and gravelly areas more common towards its deeper parts. This type of substrate diminishes the abundance of sessile organisms, with sandy patches generally colonized by the foraminifera cf. *Syringammina fragillissima*, which can be accompanied by cerianthids and the solitary scleractinian *Flabellum* sp. Areas of coarser substrate on both flanks are dominated by lithistid sponge species, replacing gorgonian corals as depth increases. Some frequent sponge species include *Leiodermatium pffeiferae*, cf. *Neophrissospongia nolitangere*, *Macandrewia azorica* and cf. *Petrosia crassa*, among many others. Also on the flanks, some aggregations of the hexactinellid sponge *Pheronema carpenteri* have been spotted, generally of a limited extension (Figure 21f). Although sponges may dominate the flanks, two coral assemblages can also be found on these deeper areas. On the southern side, gorgonians of the genus *Acanthogorgia* are found in combination with the laminate sponge cf. *Pachastrella monilifera*, whilst coral gardens formed by of the white gorgonian *Candidella imbricata* can be observed in the deepest part of the seamount, in most cases accompanied by the yellow cup coral *Leptopsammia formosa*.

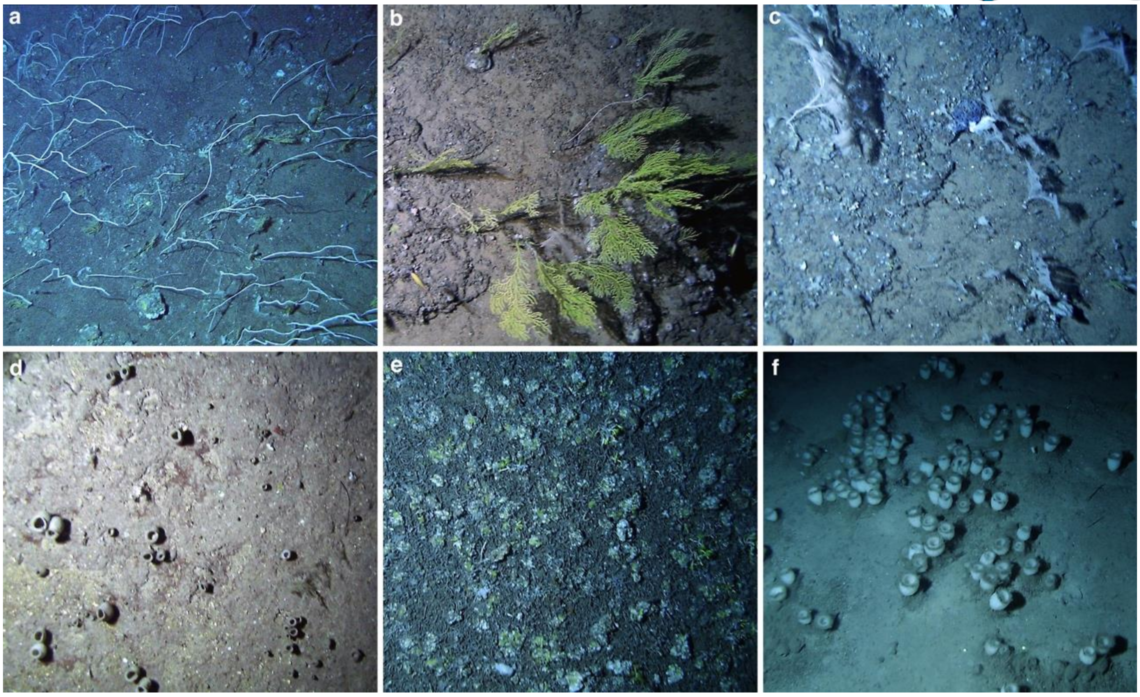

Figure 21. *Images showing some of the benthic communities that have been identified in Condor seamount. (a). Dense patch of the whip coral Viminella flagellum. (b) Aggregation of the sea fan Dentomuricea aff. meteor. (c) Some of the large Callogorgia verticillata colonies observed. (d) Aggregation of the glass sponge Asconema sp. on the eastern side of the summit. (e) Aspect of the Eguchipsammia reef found on the middle part of the summit. (f) One of the few aggregations of the hexactinellid Pheronema carpenteri. © Hopper tow-cam, NIOZ.*

3.2. Capelinhos

Depth range explored: 100 - 650 m. 18 dives.

The shallowest part of Capelinhos, closer to shore, hosts a diverse ecosystem, dominated by several invertebrate species that intermix to form benthic communities, sometimes difficult to disentangle one from the other. One of the most striking aggregations is characterized by a soft coral species yet to be identified, reaching very high densities in rocky outcrops at 100-150 m depth (Figure 22a). The number of species associated to this community is large, with numerous colonies of the black coral cf. *Antipathella subpinnata* (Figure 22b), as well as many sponges not identified to species level yet. A wide variety of fishes have also been observed within this community, including *Pontinus kuhlii*, *Phycis phycis*, *Anthias anthias*, *Helicolenus dactylopterus* and *Serranus atricauda*. Moving further deep (200-400 m), aggregations of the yellow sea fan *Acanthogorgia* sp. become very common, in some areas reaching impressive densities (Figure 22c). Although this gorgonian species is observed forming monospecific patches in some areas of Capelinhos, it is generally associated to a few other larger species, such as the octocorals *Callogorgia verticillata*, *Dentomuricea* cf. *meteor* and yellow morphotypes of the whip coral *Viminella flagellum*, as well as the sponge cf. *Haliclona implexa*, which can reach high abundances locally.

Also interesting is the aggregation of the primnoid coral *Callogorgia verticillata* (Figure 22d), with some large colonies that show little signs of fishing impact. Until now, these aggregations have only been observed in one spot, covering a very small area. Also relevant are the high abundances of large hydrozoan colonies, found forming some dense monospecific patches as well as in association with a few of the coral species already mentioned. Between 300 and 450 m depth, an impressive aggregation of the hydrocoral *Errina dabneyi* was identified (Figure 22f), possibly with the highest densities of this species reported in the Azores so far. Impressively, this community lasted for several hundreds of meters, with other coral species living in association, including *Callogorgia verticillata*, *Dentomuricea* aff. *meteor* and *Acanthogorgia* sp. The deepest dives, below 500 m, reported the lowest diversity of megafauna of all the areas explored, dominated in most cases by sand and boulders, some of which with a distinctive dark/reddish coloration that could indicate recent volcanic activity. One of the most relevant aspects of Capelinhos area is the large number of sharks that have been encountered, mainly from the species *Galeorhinus galeus*. These sharks are usually observed down to 300 m depth, with a large aggregation reported in shallower areas (150-200 m depth). Further deep, some specimens of the six gill-shark *Hexanchus griseus* have also been observed.

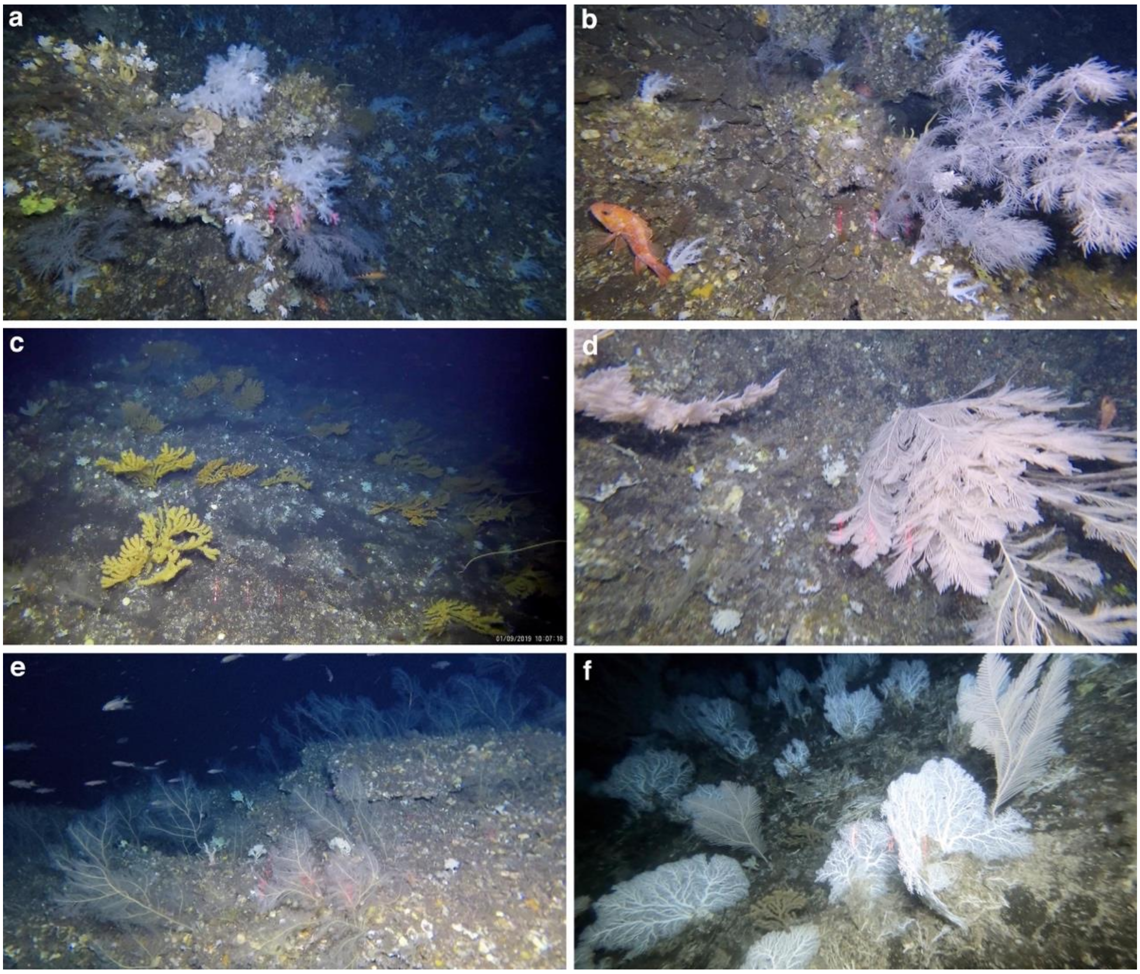

Figure 22. *Images showing some of the benthic communities that have been identified in Capelinhos area. (a) Aggregation of soft corals on the shallowest areas explored. (b) A large colony of the black coral cf. Antipathella subpinnata in between some soft corals. (c) High densities of the yellow sea fan Acanthogorgia sp. (d) Some large colonies of the primnoid coral Callogorgia verticillata. (e) Aggregation of large hydroids. (f) A dense aggregation of the hydroid coral Errina dabneyi. © Drift cam, IMAR/Okeanos UAç.*

3.3. Baixo de São Mateus

Depth range explored: 500 - 1000 m. 2 dives.

Baixo de São Mateus is an elongated feature south of Pico island that stretches for more than 20 km, with its summit at 350 m depth. Its slopes are of a sedimentary nature, with most of its rocky outcrops covered in a layer of muds and fine sands. The deepest areas explored correspond to flat soft bottoms, where some xenophyphores likely belonging to the species *Syringammina fragilissima* could be observed scattered along the seabed. When the slope begins to increase, large deposits of coral rubble half buried in the sediment start to appear, in some areas constituting a large percentage of the available substrate. Not much fauna grows on top of the coral fragments besides some small sponges and the occasional sea urchin cf. *Cidaris cidaris*. The origin of these coral deposits seems to be the cold-water coral *Lophelia pertusa*. Although it is possible that other species have also contributed to the generation of theses deposits. When the rock outcrops, especially in verticall or very slopping walls, the most important community corresponds to that formed by large colonies of the black coral *Leiopathes expansa* surrounded by a considerable number of small scleractinian corals of the species *Dendrophyllia cornigera* as well as the glass sponge Farrea occa (Figure 23a). It is interesting to point out that many dead colonies of the coral *Lophelia pertusa* still attached to the rock are commonly observed within this community. A closer examination of these colonies has revealed that some tips still have living polyps, although their percentage with respect of the dead parts is very small. Soft bottom patches around these rocky outcrops are colonized by the glass sponge *Pheronema carpenteri* (Figure 23b), which reaches some very high densities locally. In those areas, where the rock has a lower slope, some very large colonies of the coral *Hemicorallium* niobe can be spotted (Figure 23c), although never forming aggregations of a considerable number. Moving further up along the slope, the association between the primnoids *Narella bellissima* and *Narella verluysi* starts to become common, reaching its higher densities at around 750 m depth (Figure 23d). Both communities with *Pheronema* and *Narella* appear alternately in those mixed substrates until around 700 m depth.

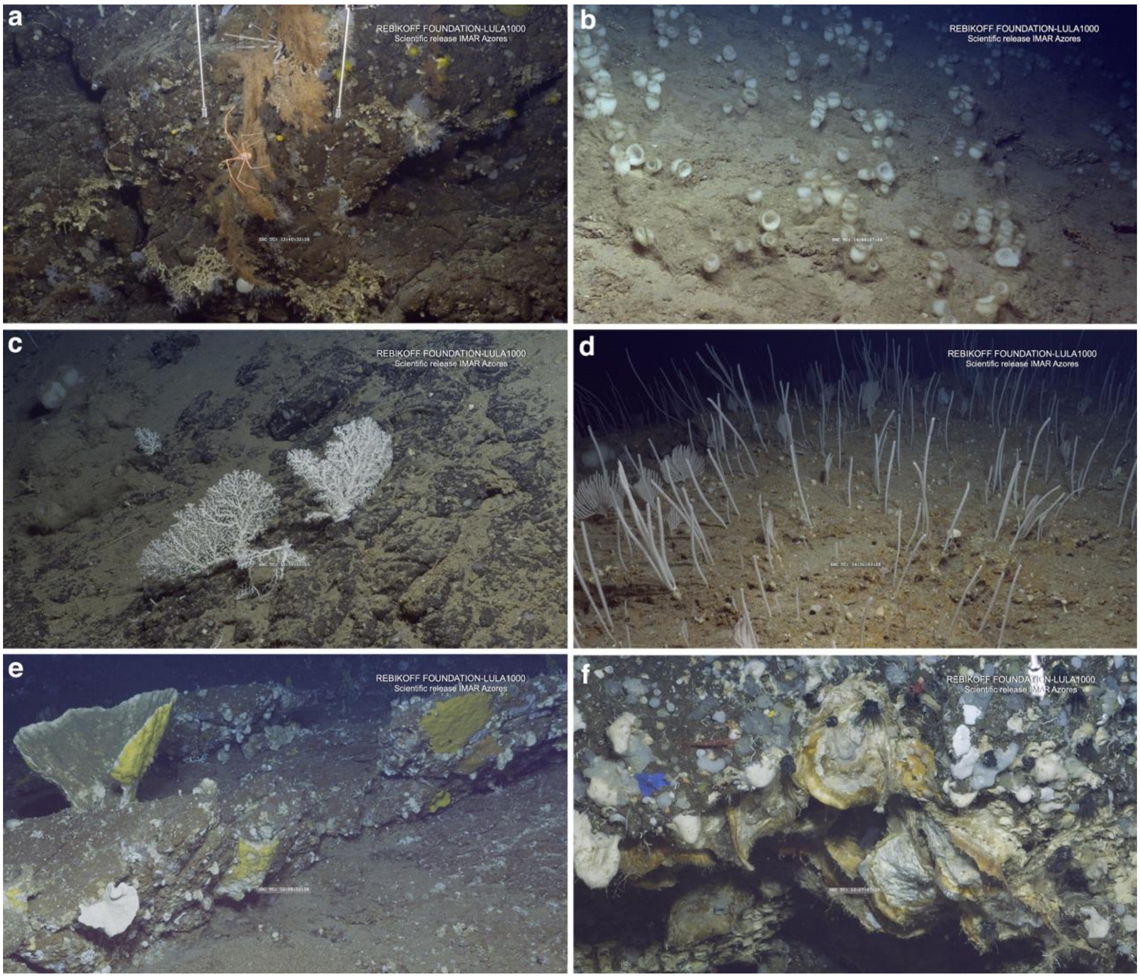

Figure 23. *Images showing some of the benthic communities that have been identified in Baixo de São Mateus seamount. (a) Large black coral Leiopathes expansa on a vertical wall at 850 m depth. (b) Field of Pheronema carpenteri on mixed substrates. (c) Two large colonies of the coral Hemicorallium niobe. (d) Dense patch of primnoid corals with a dominance of Narella verluysi. (e) Aspect of the sponge-dominated community on the hard substrates of the shallowest areas visited , with a large sponge of the species cf. Characella pachastrelloides. (f) Close up of the living fossil community with the oyster cf. Neopycnodonte zibrowii and the crinoid cf. Cyathidium foresti on a vertical wall at 580 m depth. © Lula 1000, Rebikoff Foundation.*

Below 700 m depth, the rock becomes more frequent and experiences a clear change in the composition of its characteristic fauna. Porifera becomes by far the dominant group, with giant sponges of the species cf.

Characella pachastrelloides (Figure 23e) alongside an extensive list of other erect and encrusting sponges: *Macandrewia azorica*, cf. *Petrosia crassa*, cf. *Neophrissospongia nolitangere*, cf. *Poecillastra compressa, Leiodermatium pfeifferae* and *Craniella longipilis* among many others. In some areas, the number of sponge species is impressive, some of which reaching important abundances. At those depths, some vertical walls are home to the living fossil community with the oyster cf. *Neopycnodonte zibrowii* and the crinoid cf. *Cyathidium foresti.* A large number of other species have been observed living attached to the vertical surfaces of those rocks, including the sea fan *Acanthogorgia* cf. *armata*, soft corals of the genus *Pseudoanthomastus,* the cup coral Desmophyllum dianthus and several encrusting sponges, both lithistid and hexactinellid.

3.4. Slopes of Pico island

Depth range explored: 500 - 1100 m. 3 dives.

The slopes of Pico island are mostly characterized by sedimentary environments, where most boulders and rocky outcrops are covered by a fine layer of mud and fine sand. The deepest soft-bottom areas explored are characterized by the presence of large numbers of the foraminifera cf. *Syringammina fragilissima* (Figure 24a), with a bathymetric distribution that at least covers depths between 1100 and 700 m. Within this community, the sea urchin cf. *Cidaris cidaris* is commonly observed alongside with a few cerianthids, a group seldomly observed in the Azores deep sea. Regarding other mobile species, the crustacean *Aristaeopsis edwardsiana* and several eel-like and Macrouridae fishes are also frequent within the foraminifera. The small boulders at 1000 m depth are generally colonized by small fauna, being the cup coral *Leptopsammia formosa* the most abundant species (Figure 24b). Some encrusting sponges and the octocoral *Chrysogogia agassizii* are also observed on those boulders.

Moving shallower along the slope (800-900m), deposits of coral rubble begin to appear, half buried inside the sediment. At least two scleractinian species seem to be responsible for such deposits, the reef-builders *Lophelia pertusa* and *Madrepora oculata.* Dead colonies of those species are also found still attached to the rocky outcrops, with live *Desmophyllum dianthus* growing on top of the dead colonies. The rocks also hold glass sponges of the species *Farrea occa,* the cup coral *Leptopsammia formosa* and other Caryophylliidae as well as some black corals of the species *Leiopathes expansa* (Figure 24c). Numerous small gorgonians were also observed on the boulders along the walls, including *Paramuricea* sp., *Bebryce* cf. *mollis*, *Placogorgia* sp. and *Chrysogorgia* sp. Hydrocorals were also common, mostly *Errina dabneyi*, *Pliobothrus* sp. and tiny specimens of *Crypthelia* sp. On top of these rocky outcrops, some dense fields of the glass sponge *Pheronema carpenteri* can be observed, especially growing on soft sediments (Figure 24d). Underneath bedrock overhangs, at 800 m depth, the living fossil community with the oyster cf. *Neopycnodonte zibrowii* and the crinoid cf. *Cyathidium foresti* can be observed (Figure 24e).

The slopes of the shallowest areas explored, between 500 and 800 m depth, are characterized by the presence of several lithistid sponges, including cf. *Petrosia crassa*, *Craniella longipilis*, *Leiodermatium pfeifferae*, *Neophrissospongia nolitangere*, cf. *Phakellia ventilabrum* and *Macandrewia azorica*, as well as some large individuals of the species cf. *Characella pachasterlloides* (Figure 24f). Not many coral species have been observed within this sponge community besides some sparse *Acanthogorgia* cf. *armata*, small colonies of the hydrocorals *Errina dabney*i and *Pliobothrus* sp. and the yellow black coral *Elatopathes* cf. *abietina.*

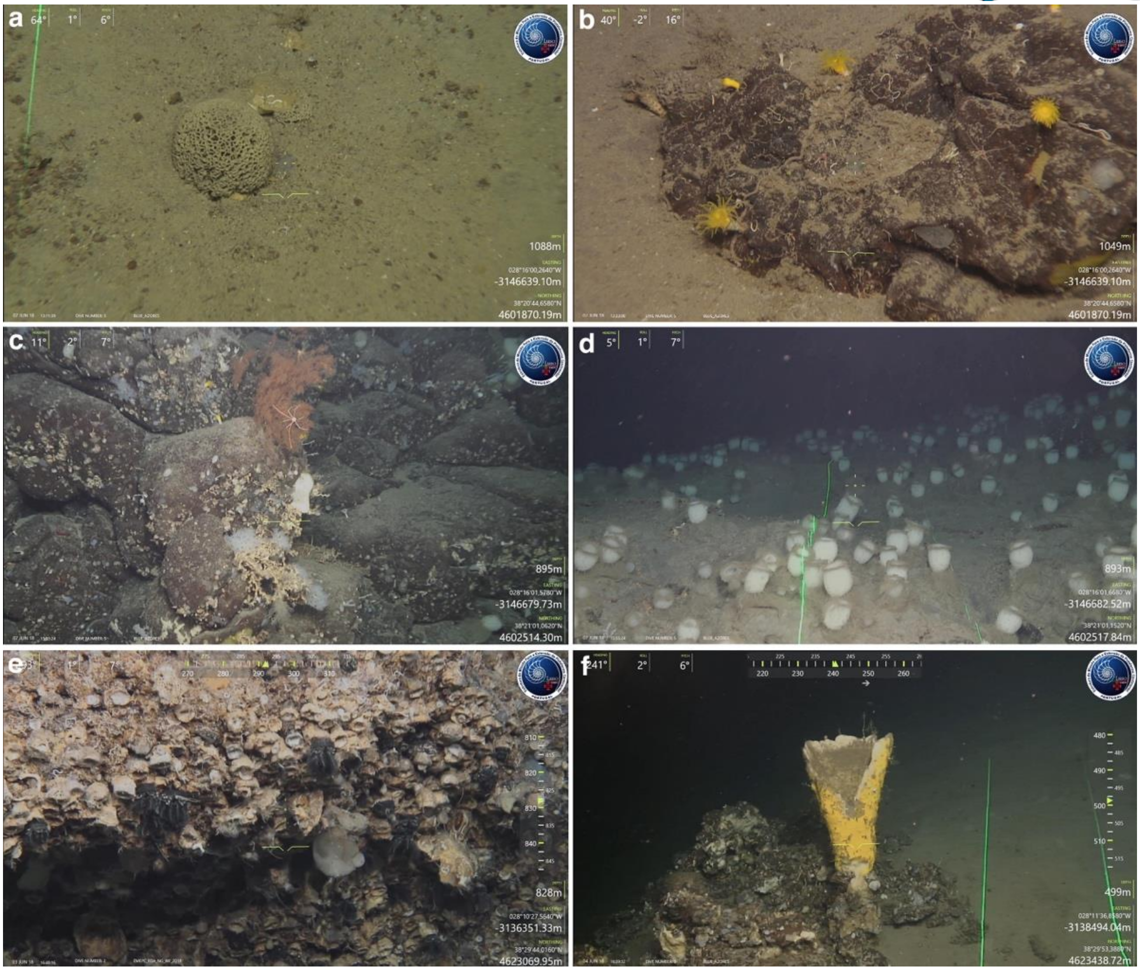

Figure 24. *Images showing some of the benthic communities that have been identified in the slopes of Pico island. (a) Soft bottom areas at 1000 m depth characterized by the presence of the foraminifera cf. Syringammina fragilissima. (b) Colonies of the yellow cup coral Leptopsammia formosa on the boulders of the deepest part of the slope explored. (c) Rocky outcrops with dead colonies of scleractinian corals, where glass sponges and the black coral Leiopathes expansa thrive. (d) Aggregations of the glass sponge Pheronema carpenteri on top of the rock overhangs. (e) Fossil community with cf. Neopycnodonte zibrowii and cf. Cyathidium foresti. (f) Large cf. Characella pachastrelloides on boulders at 500 m depth. © Luso ROV, EMEPC.*

3.5. Slopes south of São Jorge island

Depth range explored: 290 - 655 m. 1 dive.

The slopes on the southern side of São Jorge island are dominated by soft sediments, mainly muds and fine sands (Figure 25a). The number of species that can be identified on such soft-bottom areas is low, and include some flat fishes, *Helicolenus dactylopterus, Hoplostethus mediterraneus* and several Macrouridae. When the rock outcrops, it is generally covered by a layer of fine sediment. In those cases, the invertebrate community is dominated by small encrusting and erect sponges, including cf. *Petrosia* crassa, *Leiodermatium pfeifferae*, cf. *Neophrissospongia nolitangere* and *Macandrewia azorica* (Figure 25b-c), as well as some blue *Hymedesmia* sp. Highest sponge abundances have been observed at about 350 m depth.

The number of corals identified in this area is low, occasionally appearing on some of the rocky outcrops. The most common species observed are generally of a small size, and include *Nicella granifera*, *Muriceides* sp., *Swiftia* sp., *Caryophylliidae* and also *Acanthogorgia* cf. *hirsuta* (Figure 25d). Some colonies of the hydrocoral *Errina dabneyi* have also been spotted, but never generating dense aggregations similar to those identified in shelf areas of other islands. At around 400 m depth, a community formed by the oyster cf. *Neopycnodonte zibrowii* and the crinoid cf. *Cyathidium foresti* has also been observed.

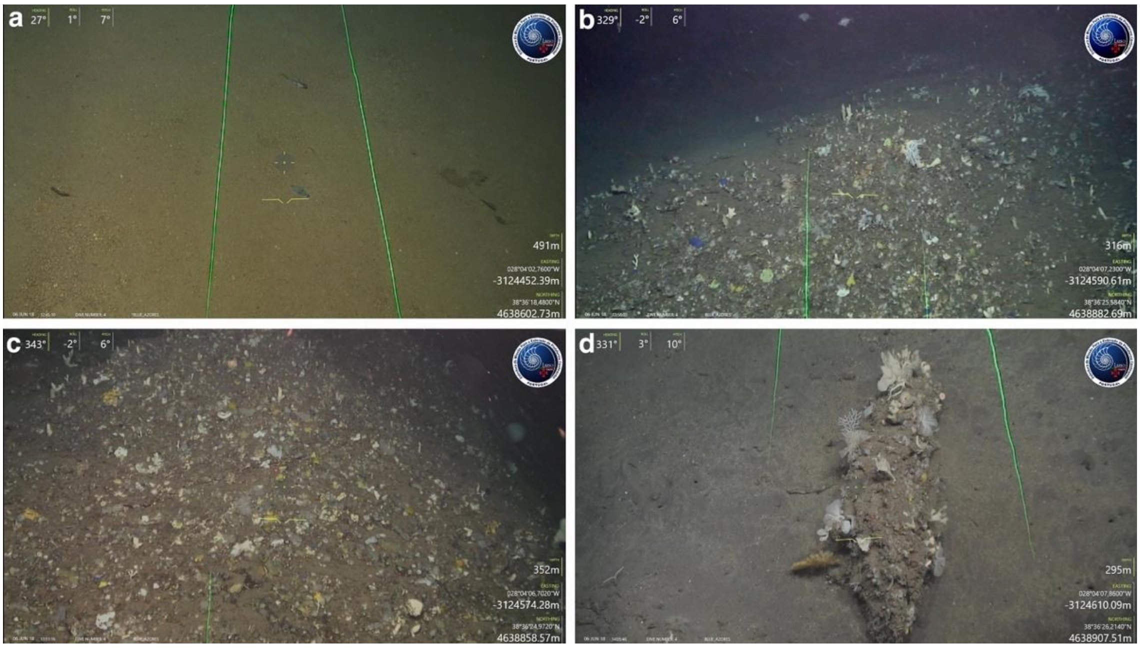

Figure 25. *Images showing some of the benthic communities that have been identified in the slopes south of São Jorge island. (a) Aspect of the soft bottoms found in many parts of the slope. (b-c) Small sponges on the rocky outcrops covered by a fine layer of sediment. (c) Small boulder with coral species attached, including Errina dabneyi and Acanthogorgia sp. © Luso ROV, EMEPC.*

3.6. Seamounts southeast of Pico

Depth range explored: 220 - 535 m. 1 dive.

The seamounts south-east of Pico represent one of the most diverse and structurally complex ecosystems observed on the shelf environments around the islands of the central group. The summits and upper slopes of the different small seamounts southwest of Pico are generally dominated by several species of cold-water corals, whose abundances vary across and within mounds. The presence of colonies of many structural species that intermix at varying densities generates a very interesting seabed habitat that will require a thorough evaluation in the near future. Dense aggregations of the hydrocoral *Errina dabneyi* are commonly observed on those mounds located closer to shore (Figure 26a). The number of associated species within this community is not high, but includes other coral species, such as the antipatharian cf. *Antipathella subpinnata* and the sea fan *Acanthogorgia* sp., together with a wide variety of small encrusting and erect sponges. Not many demersal fish species have been observed associated to this community besides some *Hoplostethus mediterraneus* and *Helicolenus dactylopterus*.

The sea fan *Acanthogorgia* sp., found in small numbers within the *Errina* community, generates very dense patches in some of the mounds located further offshore (Figure 26b). This sea fan is generally observed accompanied by other coral and sponge species, including *Vininella flagellum*, *Callogorgia verticillata* and *Paracalyptrophora josephinae*. In fact, this last primnoid coral becomes very common in some areas, with colonies reaching some of the largest sizes recorded for the Azores region (Figure 26c). Colonies of the yellow octocoral *Dentomuricea* aff. *meteor* also appear scattered within the *Acanthogorgia* aggregations, but they can also form patches of high densities, sometimes even higher than those reached by *Acanthogorgia* (Figure 26d). Also within the *Acanthogorgia* community, some very dense aggregations of the primnoid *Callogorgia verticillata* have been identified (Figure 26e), generally more restricted in space than the actual *Acanthogorgia* aggregations. The colonies that make up these dense *Callogorgia* patches are always of a moderate size, especially if compared to those found in areas of the MAR.

Several sponge aggregations have also been observed on the slopes of the seamounts southeast of Pico. The species composition of this community is extensive, and includes a wide variety of small encrusting and erect sponges. Among the larger Porifera, the most common species is the giant sponge cf. *Characella pachastrelloides*, together with *Macandrewia azorica* and cf. *Neophrissospongia nolitangere,* as well as the glass sponge *Asconema* sp., among others. Finally, one of the most interesting communities observed in the mounds SE Pico corresponds to the reefs formed by large numbers of the azooxanthellate scleractinian coral *Eguchipsammia* (Figure 26f). Until now, those reefs have only been observed in one of the mounds of SE Pico at 350 m depth, but it is very likely that such reefs exist in other seamounts in the region. A large number of accompanying species were identified within those reefs, with a species composition similar to that of the *Acanthogorgia* community.

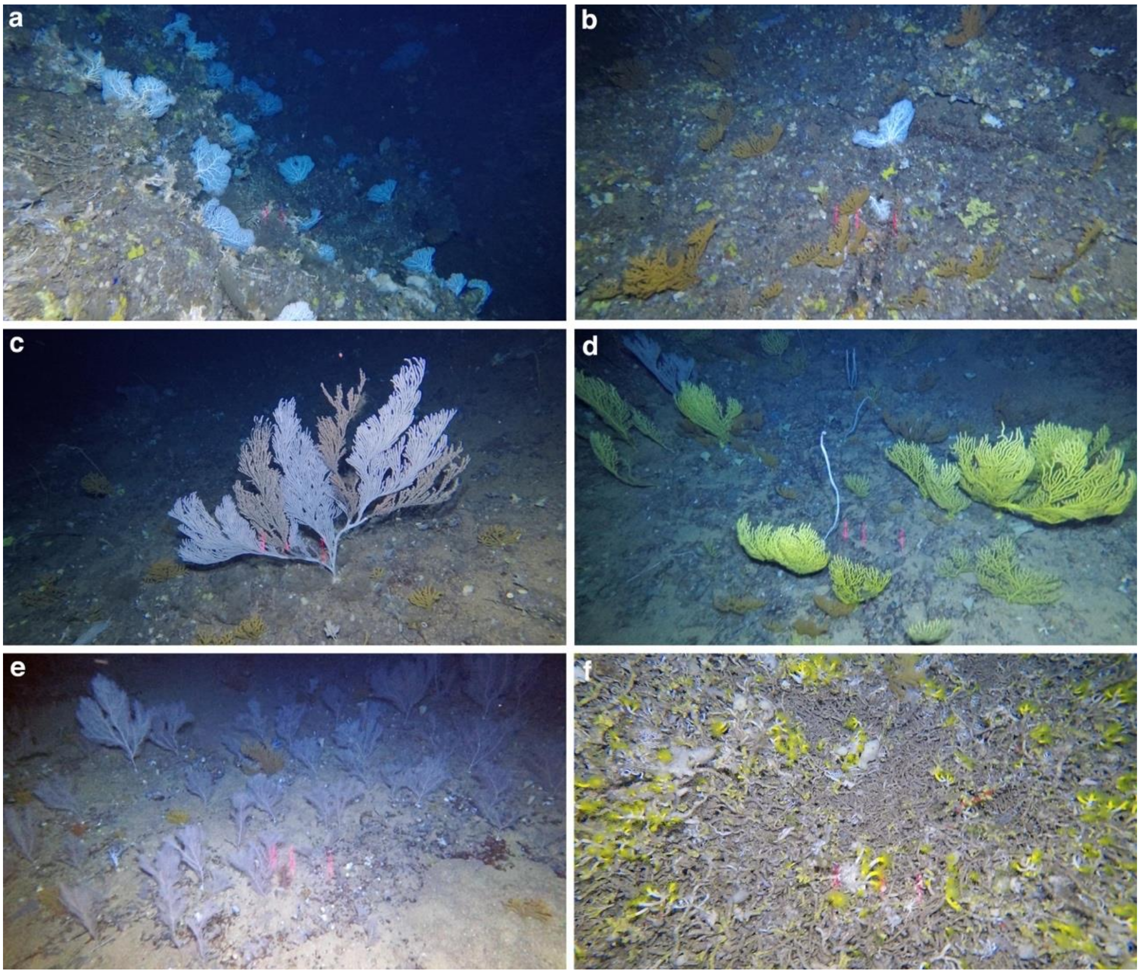

Figure 26. *Images showing some of the benthic communities that have been identified in the seamounts south-east of Pico island. (a) Some high densities of the stylasterid Errina dabneyi that can be found on the slopes of some seamounts. (b) Aggregation of Acanthogorgia sp. (c) Large colony of the primnoid Paracalyptrophora josephinae with three of its branches epiphyted by the zoanthis Zibrowius alberti. (d) Some large colonies of the species Dentomuricea aff. meteor. (e) A very dense aggregation of Callogorgia verticillata on mixed substrates. (f) Aspect of the Eguchipsammia reef encountered on one mound far away from shore. © Drift cam, IMAR/Okeanos UAç.*

3.7. São Jorge de Fora

Depth range explored: 500 - 1300 m. 4 dives.

São Jorge de Fora seamount is an elongated feature south of Terceira island that stretches for 21 km. A very clear zonation pattern regarding the structure of the benthic communities can be observed in this seamount, with very well-defined species associations along the depth gradient. Overall, the area shows a high degree of sediment deposition and low number of organisms within the communities identified. The deepest areas explored, at the base of the seamount, are characterized by flat soft bottoms with muds and fine sands, where the most important megafauna species is the foraminifera cf. *Syringammina fragilissima*. Not many species have been be identified within this community besides some sea urchins of the species cf. *Cidaris cidaris* and sparse *Acanella arbuscula* corals, together with some large crustaceans of the species *Aristaeopsis edwardsiana* (Figure 27a). Aggregations of the primnoids *Narella bellissima* and *Narella verluysi* can be observed on flanks of the seamount, accompanied by the sea urchins cf. *Cidaris cidaris* and cf. *Echinus sp.*, the yellow cup coral *Leptopsammia formosa* and the large sponge *Pheronema carpenteri* (Figure 27b). At around 600 m depth, an aggregation of large gorgonians of the species *Callogorgia verticillata* has been observed, with relatively high densities in some local patches, which several tens of meters (Figure 27c). On the summit, at around 500 m depth, the hard substrates are mostly colonized by gorgonians of the species *Viminella flagellum* (Figure 27d), accompanied by other corals such as *Paranthipathes larix*, *Pseudoanthomastus* cf. *agaricus* and *Acanthogorgia* sp., the white sea urchin cf. *Echinus sp.* and many encrusting sponges.

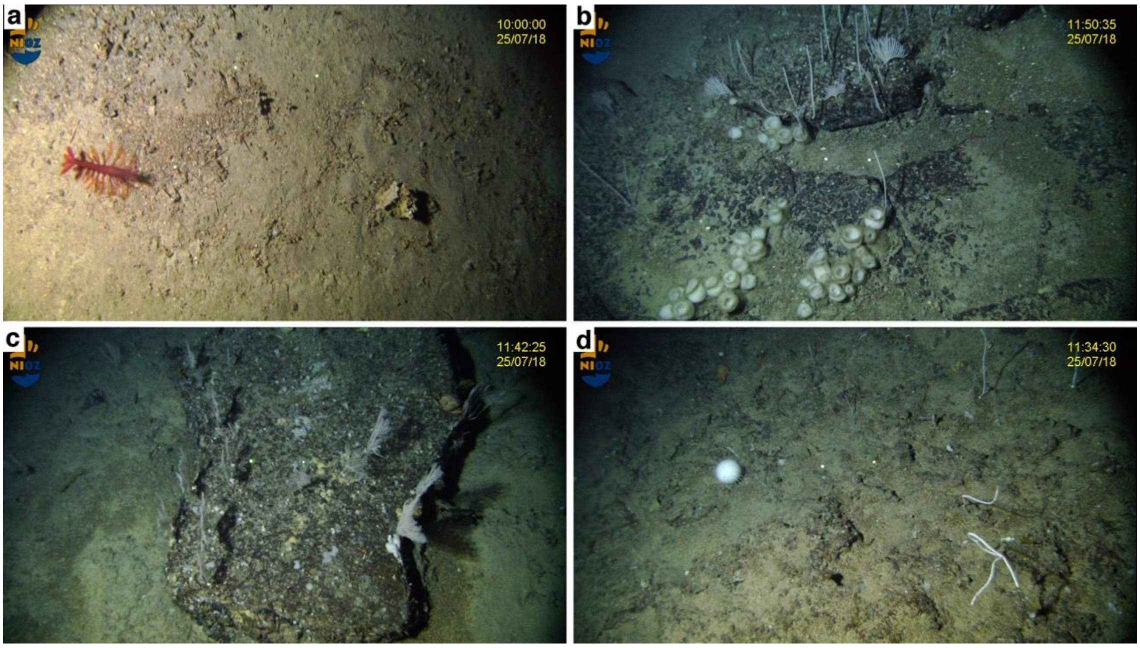

Figure 27. *Images showing some of the benthic communities that have been identified in the São Jorge de Fora seamount. (a) One specimen of the shrimp Aristaeopsis edwardsiana on the soft bottoms below 1000 m depth. (b) Association between the corals Narella spp. and the glass sponge Pheronema carpenteri. (c) One of the few aggregations of the primnoid Callogorgia verticillata. (d) Sparse colonies of the whip coral Viminella flagellum on the summit. © Hopper tow-cam, NIOZ.*

3.8. Slopes south of Terceira

Depth range explored: 500 - 830 m. 3 dives.

The deepest areas explored on the southern slopes of Terceira island are characterized by large deposits of soft sediments (mostly muds and fine sands) and scattered boulders. These areas host a small number of megabenthic species, with very few organisms of a large size observed. The soft substrates of the deepest areas explored are mainly characterized by the foraminifera cf. *Syringammina fragilissima,* which appears with a few other mobile species such as the crustacean *Aristaeopsis edwardsiana,* as well as fish species including *Chaunax* sp. (Figure 28a) and deep-sea sharks of the species *Dalathias licha.* When the rock outcrops, sponges are the main group that can be identified, including the species *Leiodermatium pfeifferae*. Towards shallower depths, the rocky outcrops start to be colonized by the yellow cup coral *Leptopsammia formosa* (Figure 28b), which can reach relatively high densities, and is generally found together with other coral species such as *Pseudoanthomastus* cf. *agaricus*, *Pleurocorallium johnsoni* and small sponge species, always in very low numbers. Further up on the slope, some coral deposits can be observed, with some isolated *Pheronema carpeteri* sponges using them as substrate for attachment. The shallowest areas visited hold two distinct benthic communities, one characterized by the presence of some large gorgonians of the species *Paragorgia johnsoni*, some of which showed signs of being affected by the fishing activity (Figure 28c), with a large number of small anthozoans likely to belong to 3 different species. and the other dominated by the whip coral *Viminella flagellum,* which becomes the most abundant coral species, although in low numbers overall (Figure 28d).

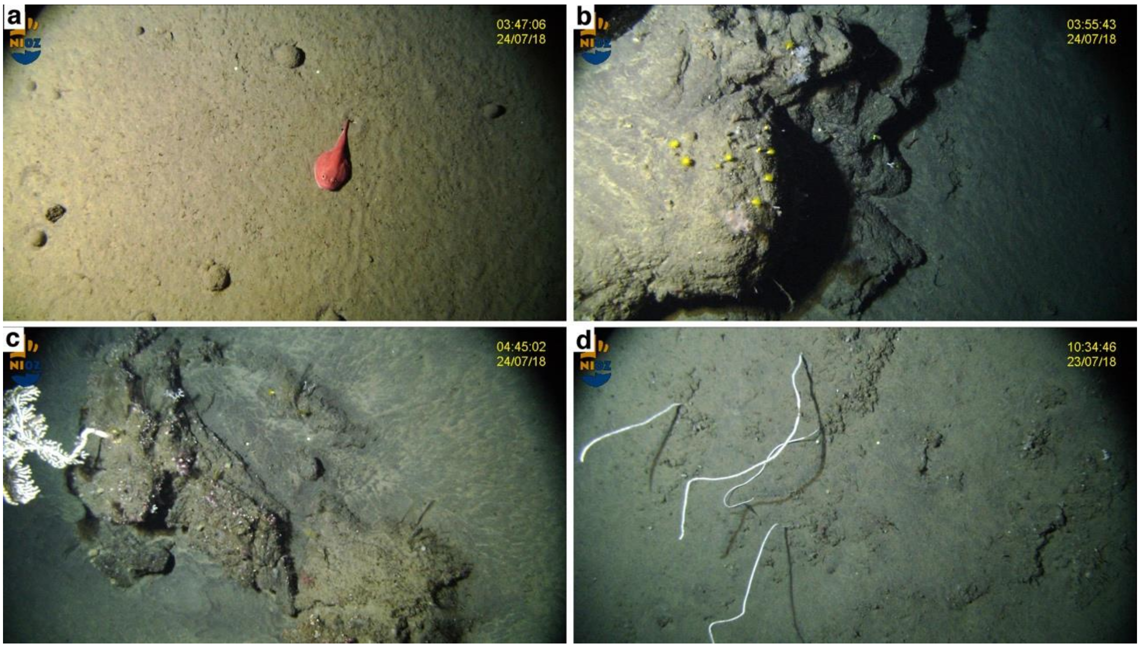

Figure 28. *Images showing some of the benthic communities that have been identified in the slopes south of Terceira. (a) Chaunax sp. over the soft bottom areas characterized by the aggregation of the foraminifera cf. Syringammina fragilissima. (b) Colonies of the yellow cup coral Leptopsammia formosa on the boulders of the lower part of the slope. (c) One of the few large colonies of the coral Paragorgia johnsoni with many small soft corals growing around its base. (d) Sparse colonies of the whip coral Viminella flagellum. © Hopper tow-cam, NIOZ.*

3.9. Dom João de Castro seamount

Depth range explored: 220 - 475 m. 4 dives.

Dom João de Castro is a volcanic seamount located between the islands of Terceira and São Miguel. This seamount was formed after a volcanic eruption that occurred in 1720, generating a small island of 150 m height. Erosional processes made the island disappear, and the top of the seamount is currently found below sea surface, at 13 m depth. Its deepest part explored, at around 500 m depth, is dominated by the white coral *Pleurocorallium johnsoni*, accompanied by the soft coral *Pseudoanthomastus* cf. *agaricus,* found mostly on the rocky outcrops. In contrast, the composition of the benthic communities dwelling a little shallower, between 300 and 450 m depth, is dominated by the primnoid *Callorgorgia verticillata* found forming relatively dense aggregations with some very large colonies (Figure 29a-b). Not many coral colonies showed signs of fishing impacts, although a considerable number of small fishing lines were observed laying over the seabed or entangled around rocks (Figure 29c). The whip coral *Viminella flagellum* and the large hydrozoan cf. *Lytocarpia myriophyllum* can also be observed as accompanying species, but never forming dense patches. In the shallower areas of the summit, the mixed substrates have a very different species composition, with a large number of small Porifera, such as an erect reptant sponge for which identification has not yet been possible (Figure 29d), together with some sparse individuals of larger sizes of the species cf. *Petrosia crassa* and *Leiodermatium* spp.

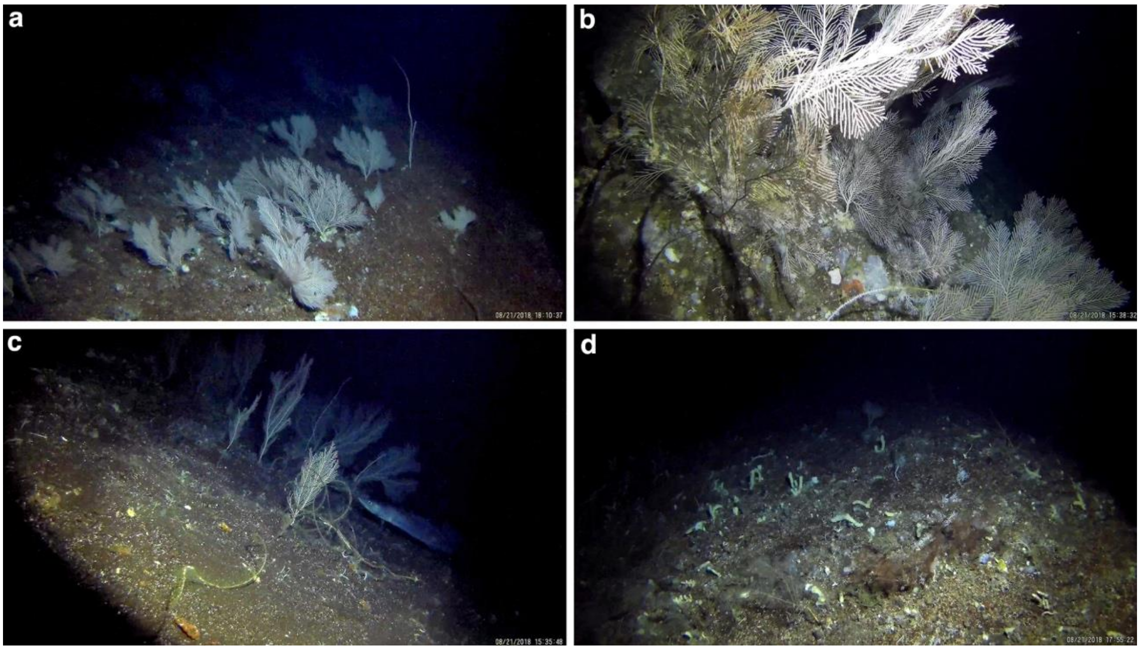

Figure 29. *Images showing some of the benthic communities that have been identified in Dom João de Castro seamount. (a-b) Aggregations of the primnoid coral Callogorgia verticillata, which reach very large sizes in Dom João de Castro seamount. (c) One of the many fishing lines found in this seamount. (d) Small reptant sponges on the mixed substrates of the summit. © Drift cam, IMAR/Okeanos UAç.*

4. Eastern group

The Eastern group encompasses the islands of São Miguel and Santa Maria. In this area, the number of features explored is limited to 3 seamounts: Alcatraz, Mar da Prata and Formigas (Figure 30). The extension of each geomorphological feature is shown in Figure 31.

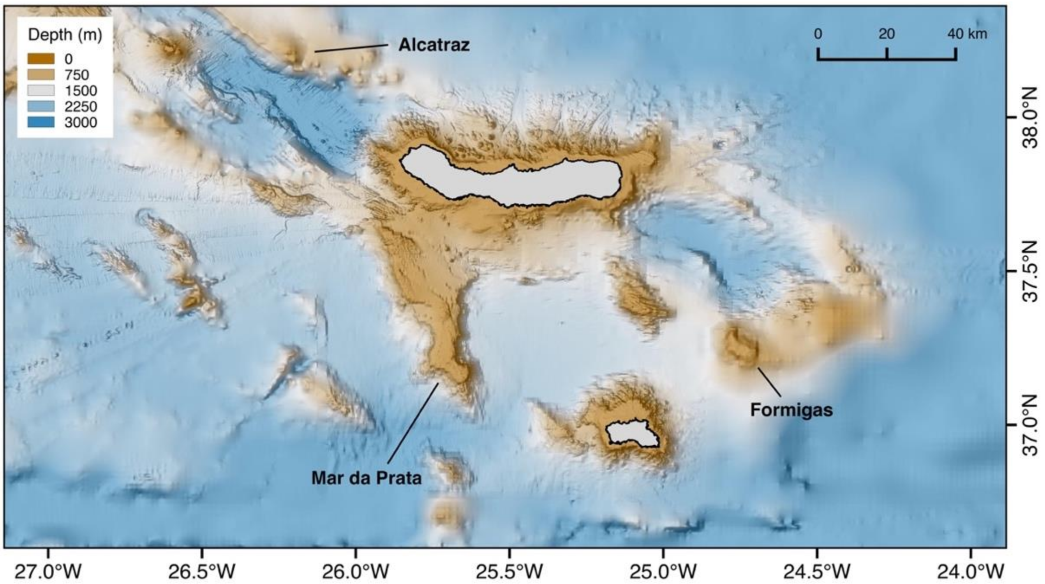

Figure 30. *Location of the different features explored on the islands of the Eastern group during the past 5 years.*

The underwater features of the Eastern group were visited during 2 different oceanographic cruises in the summers of 2017 and 2018 on board of the and N/I Arquipélago. In total, 17 underwater dives have been performed in these 3 areas until now, with an asymmetric sampling effort (Table 3). Formigas is the seamount better evaluated, with 10 ROV dives that cover a depth range between 500 and almost 1600 m depth. All dives were planned so that all depths were prospected, providing a complete understanding of the bathymetric patterns of species distribution. The other 2 seamounts were explored using the drift-cam system developed at IMAR, although in its first design. During those dives, the number of entanglements with fishing lines was large, limiting the capacity to successfully explore a wider area. For this reason, the number of dives is very limited and only covering a narrow depth range.

Table 3. *Number of dives and platform used to explore each of the seamounts of the Eastern group. Depth indicates the shallowest and deepest points reached across all dives in each feature. Seamounts are ordered following a longitudinal gradient, from west to east.*

Seamount/feature	**Area (km^2)**	**Survey**	**Year**	**Platform**	**Dives**	**Depth (m)**
Alcatraz	55	MapGES 1	2018	Drift-cam	4	360 - 560
South of Mar da Prata	215	MapGES 1	2018	Drift-cam	3	300 - 410
Formigas	249	MedWaves	2017	Liropus ROV	10	480 - 1580

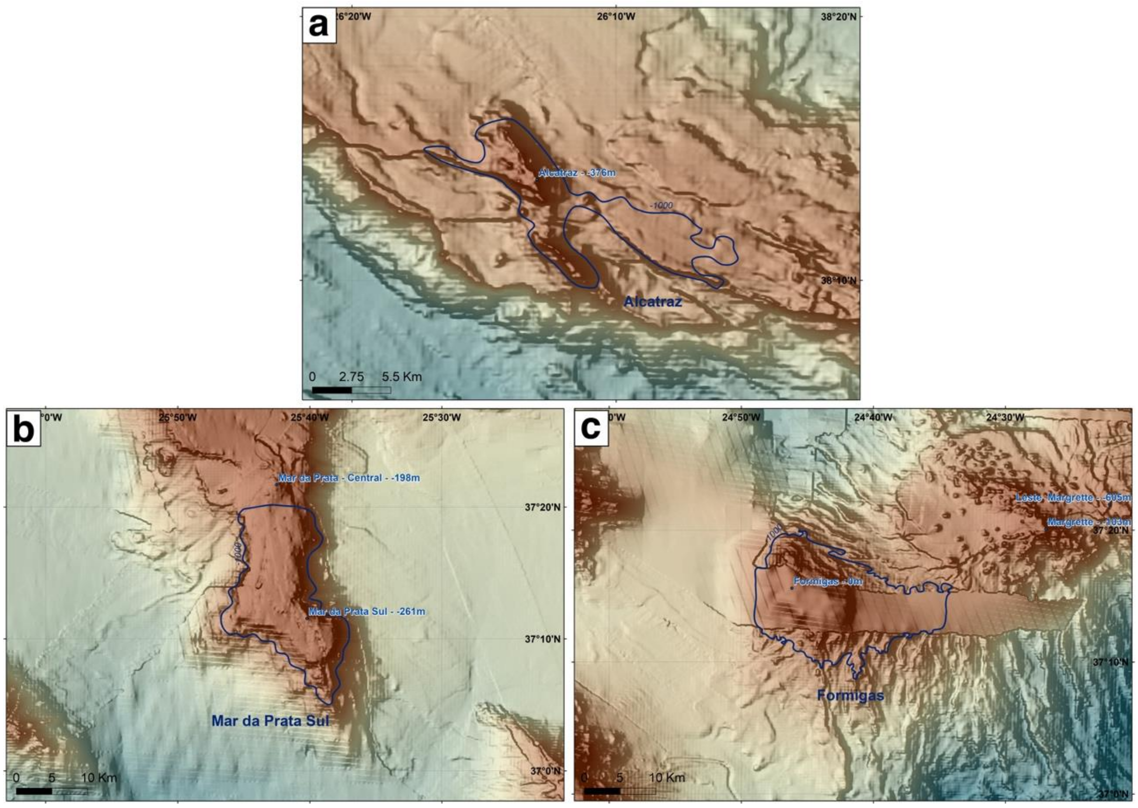

Figure 31. *Extension of each geomorphological feature evaluated in the eastern group (black lines). (a) Alcatraz seamount. (b) South of Mar da Prata seamount. (e) Formigas seamount.*

4.1. Alcatraz seamount

Depth range explored: 360 - 560 m. 4 dives.

Alcatraz is a relatively deep seamount located only 18 nm east of Dom João de Castro, with the shallowest point of its elongated summit at 360 m depth. Several large sponge species have been observed on its rocky outcrops, in which to include the litisthids *Leiodermatium pfeifferae*, *Leiodermatium lynceus*, cf. *Neophrissospongia nolitangere* and cf. *Petrosia crassa* (Figure 32a), as well as the giant sponge cf. *Characella pachastrelloides* (Figure 32b). Sparse colonies of the whip coral *Viminella flagellum* have also been spotted among the sponges, some of them reaching very large sizes. Monospecific patches of this whip coral have also been reported on the shallowest part of the seamount, although never in high densities (Figure 32c). Some large solitary colonies of the coral *Callogorgia verticillata* have also been reported in Alcatraz, but always scattered along the seabed (Figure 32d). Alcatraz seamount is also characterized by the large number of fishing lines that have been observed laying over the seabed, some of which seem to have been abandoned in recent times due to the large number of small species growing on top.

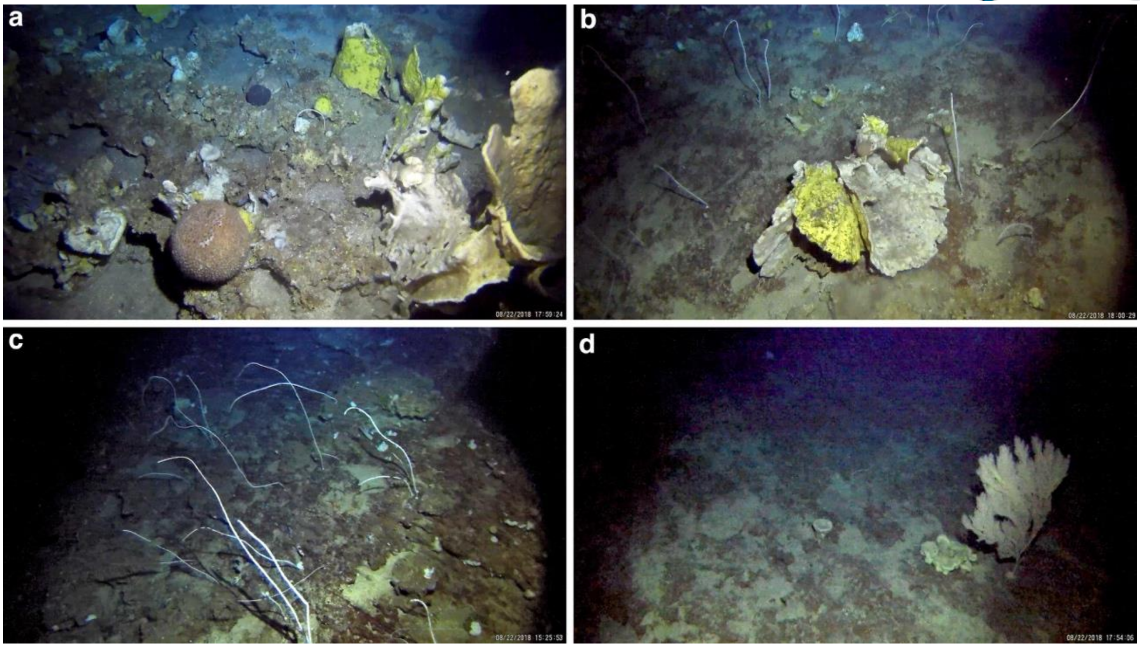

Figure 32. *Images showing some of the benthic communities that have been identified in Alcatraz seamount. (a-b) Areas of hard substrates of the summit with large Porifera, including the tubular cf. Characella pachastrelloides and the spherical Craniella longipilis. (c). Some whip coral colonies of the species Viminella flagellum. (d) One of the few scattered colonies of the primnoid Callogorgia verticillata. © Drift cam, IMAR/Okeanos UAç.*

4.2. South of Mar da Prata seamount

Depth range explored: 300 - 410 m. 3 dives.

Mar da Prata is a large elongated underwater feature located between the islands of São Miguel and Santa Maria and known for its historic fishing pressure. Only the summit of the southern sector has been explored until now, and information is currently available only for a limited bathymetric range. The flat areas of the summit are characterized by sand and fine gravels, with very little invertebrate fauna reported so far. When boulders start to appear in between patches of sand, the community is characterized by several lithistid sponges, some of which of relatively large sizes. Common Porifera include *Leiodermatium lynceus* and *Leiodermatium pfeifferae, Macandrewia azorica* and cf. *Petrosia crassa* (Figure 33a), as well as a white laminate sponge that resembles *Phakellia robusta*, but for which further identifications are needed (Figure 33b). The only coral species observed in the mixed substrates of Mar da Prata is *Viminella flagellum,* always observed as scattered colonies. Conversely, on the southeastern side of the mound, the hard substrates of the upper slopes host a very well-structured community characterized by the yellow sea fan *Dentomuricea* aff. *meteor* in very high densities, accompanied by the sea whip *Viminella flagellum* (Figure 33c-d). As expected, areas of high relief in this seamount have a large number of abandoned fishing lines.

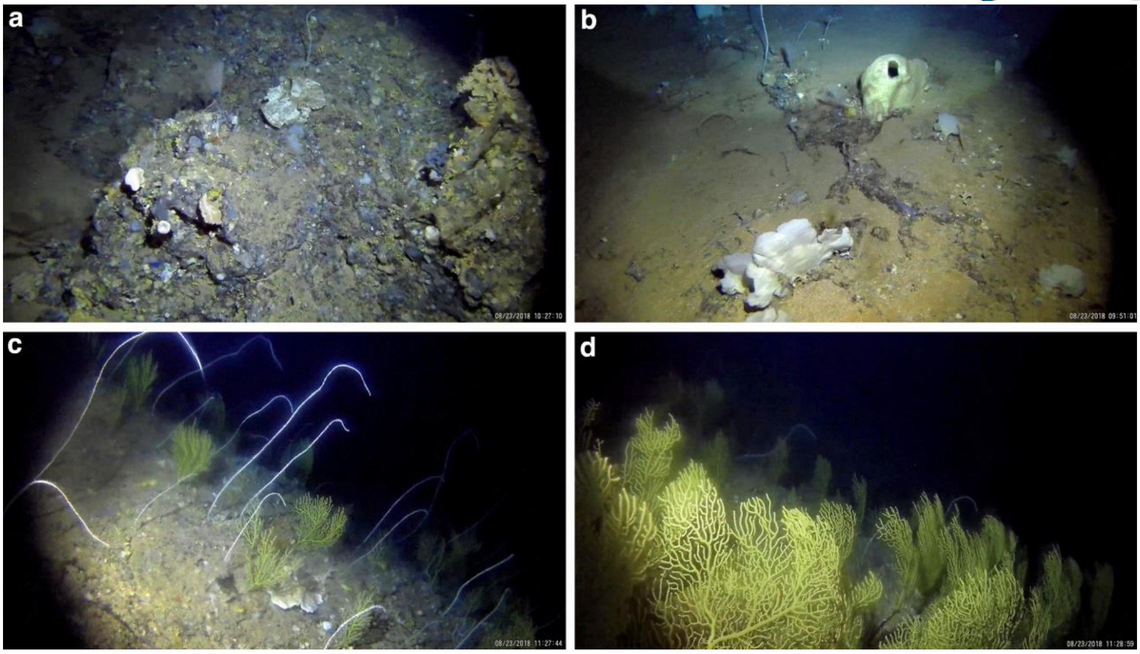

Figure 33. *Images showing some of the benthic communities that have been identified in Mar da Prata seamount. (a) Some lithistid sponges on hard substrates. (b) Other unidentified Porifera of the summit. (c-d) Dense aggregation of the sea fan Dentomuricea aff. meteor on the southwestern flank of the Mar da Prata. © Drift cam, IMAR/Okeanos UAç.*

4.3. Formigas seamount

Depth range explored: 490 - 1580 m. 10 dives.

Formigas seamount corresponds to the easternmost feature that has been explored in the Azores region. It is located 34 miles south-west of São Miguel island, in the easternmost part of the Terceira Rift, at the western end of the Eurasian–Nubian plate boundary. It is known to be under the influence of the Mediterranean Outflow Water (MOW), which provides a particular oceanographic setting to the configuration of its water masses. According to the video data, Formigas must be considered a diverse seamount, with more than 160 invertebrate morphospecies identified so far. The deepest areas explored, at 1400-1600 m depth, are mostly flat with soft sediments, where sand forms in some areas very discernible ripples (Figure 34a). Not much fauna can be observed in these soft bottoms besides some scattered sea urchins cf. *Cidaris cidaris* and the orange octocoral *Acanella arbuscula*, which has been observed in relatively high densities on soft bottoms of the southern flank (Figure 34b). More abundant is the mobile fauna, which includes among others the crustacean *Aristaeopsis edwardsiana* and several eel-like and macrourid fishes.

Moving towards shallower depths, when the rock starts to outcrop, the number of species increases rapidly, leading to a very diverse mixed community of corals and sponges, although generally with low densities. This community is very common along a large bathymetric range, reaching areas as shallow as Very common are the black corals *Bathypathes patula, Antipathes dichotoma* and *Paranthipathes larix,* as well as *Leiopathes expansa*, some of which reach large sizes. Also common are the octocorals *Acanella arbuscula, Chrysogogia agassizii, Iridogorgia* cf. *pourtalesii* and several Plexauridae species still to be identified, together with the bamboo coral *Keratoisis* sp., with some colonies of impressive heights (Figure 34c). It is interesting to highlight the presence of some alive colonies of the scleractinians *Lophelia pertusa* and *Desmophyllum dianthus*, although always found scattered and in low numbers. Regarding the sponge fauna, some hexactinellid species can be found on the rocks, including *Pheronema carpenteri*, cf. *Phakelia ventilabrum* and *Euplectella* sp, as well as large desmosponges such as cf. *Poecillastra compressa*. The highest structural complexity of this community has been observed in the large rocky outcrops that can be found on the southern flank at around 1000 m depth (Figure 34d). In this situation, most coral species reach their maximum sizes and densities, conforming the highest diversity patches identified in this seamount so far. Also at those depths, the octocoral *Candidella imbricata* become very common, both as part of the coral community or as the dominant species together with *Hemicorallium niobe* and an orange Plexauridae still to be identified (Figure 34e). Around 1200 m depth, in an area of compact soft sediments of the southern flank, one of the largest aggregations of the lollypop sponge *Stylocordyla pellita* ever observed in the Azores was encountered (Figure 34f). This pedunculate sponge is found in association with the orange octocorals *Acanella arbuscula* and *Chrysogorgia agassizi,* which develop both on hard and soft substrates. In fact, these two species are the most widespread corals of the deep areas of Formigas, found in low densities from 1400 m all the way to 700 m depth.

Figure 34. *Images showing some of the benthic communities that have been identified in Formigas seamount. (a) Ripples on the soft bottoms of the deepest areas explored, at 1500 m depth. (b) Some of the large number of Acanella arbuscula colonies identified in the deep-sea areas of Formigas. (c) A large Keratoisis sp. in areas of a high diversity of coral species. (d) Aspect of the large rocky outcrops colonized by an impressive number of cold-water corals, including several species of scleractinians, octocorals, black corals and bamboo corals. (e) Association between Candidella imbricata and Hemicorallium niobe, together with an orange Plexauridae still to be determined. (f) One of the densest aggregations of the pedunculate sponge Stylocordyla pellita registered in the deep-sea areas of the Azores so far. (g) Dead colonies of the scleractinian Lophelia pertusa. (h) Ancient community found in vertical walls with cf. Cyathidium foresti. (i). Dense aggregation of the Primnoid Narella versluysi with a few other corals and glass sponges. © Medwaves, ATLAS project.*

The quantity of coral rubble deposited over the seabed starts to increase below 1000 m, with areas fully covered by pieces of dead corals. Most of these pieces seem to be originated by the fractioning of large colonies of the scleractinian coral *Lophelia pertusa,* but some fragments are also as remnants of solitary cup corals and even colonies of lace corals (Stylasteridae). In some sloping and vertical walls, some dead colonies are clearly visible due to their size of several centimeters (Figure 34g), and now serve as substrate for other invertebrate species to attach to. Also on these vertical walls of the southern flank, at around 900 m depth, the 'living-fossil community' of the crinoid cf. *Cyathidium foresti* can also be identified, together with several brachiopods and encrusting and hexactinellid sponges attached to the rock (Figure 34h).

Shallowest areas, both on the northern and southern flanks (650-800 m), host a community characterized by large densities of the primnoids *Narella versluysi* and *Narella. Bellissim* (Figure 34i), which appear associated to a wide array of species, including the gorgonian *Acanthogorgia* sp. and *Hemicorallium tricolor*, as well as the sponges cf. *Poecillastra compressa* and *Pheronema carpenteri.* The shallowest areas explored show fewer structuring species and are dominated by sponges, mainly encrusting and digitate of a small size. The density of sponges is generally larger in rocks of a darker coloration, possibly of a basaltic origin.

5. Vulnerable Marine Ecosystem in the Azores deep-sea

As described above, IMAR has led or participated in several oceanographic surveys that made use of imaging technology to better understand the diversity and distribution of deep-sea benthic fauna by focusing on 25 underwater features across the EEZ of the Azores (Figure 35). The spatial extent of the video transects carried out until now is vast and covers a large number of seamounts, ridges and slopes between 100 and 1500 m depth. The largest sampling effort has been placed in the Mid-Atlantic Ridge, where 18 features have now been inspected, including 6 seamounts/ridges that belong to the Gigante Seamount Complex. More than 130 dives have now been successfully completed along the MAR covering a depth range of 180-1500 m. The islands that belong to the central group have also been thoroughly explored, with more than 50 dives in 9 seamounts and island slopes located in their close proximity, covering depths of 100-1300 m. Finally, only 3 features have been investigated until now around the islands of the eastern group, with just over 15 dives covering depths of 350-1500 m. The list of benthic communities identified in the Azores so far, and its presence in the different features is provided in Table 4.

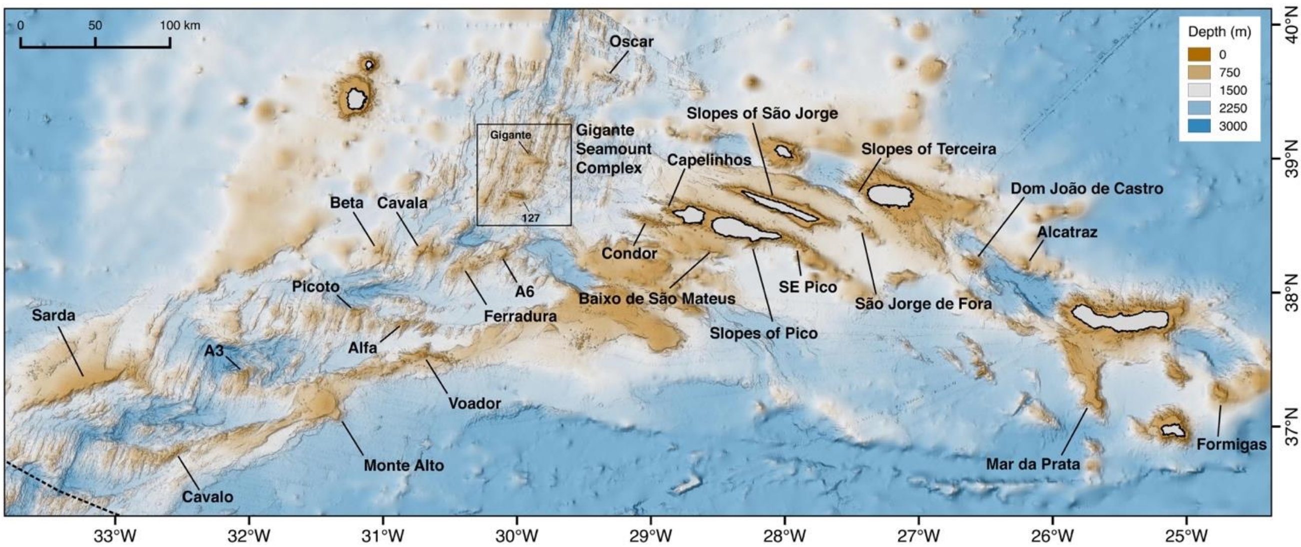

Figure 35. Location of the underwater features that have been visually investigated by means of ROVs, tow cams and manned submersibles across the Azores EEZ in the last decade.

5.1. Vulnerable Marine Ecosystem indicator biological communities in the Azores

Based on the video footage evaluated so far, the deep-sea areas of the Azores should be regarded as very diverse ecosystems, home to a large number of megabenthic species (Figure 36.). Unlike other areas of the North Atlantic, the main species providing tridimensional structure to the seabed of the Azores correspond to large gorgonian corals (Octocorallia, Alcyonacea), with many representatives of the suborders Holaxonia and Calcaxonia. Some examples would include the species *Viminella flagellum* and *Callogorgia verticillata* (Calcaxonia) but also *Dentomuricea* aff. *meteor* and *Acanthogorgia* spp. (Holaxonia). These four octocoral species thrive in hard surfaces of summits and upper slopes of most seamounts and ridges explored (Table 4), and are less frequently observed on the island slopes, especially those with high sedimentation rates. These corals can form very dense coral gardens, which are home to a wide variety of associated species, including mobile fauna such as fish and crustaceans (Figure 36.a-b). The dominance in terms of abundance of one species over the others within this community is still a matter of study, and all possible combinations have been reported so far in the Azores region. The most common situation is that where the whip coral *Viminella flagellum* and/or the primnoid *Callogorgia verticillata* become the dominant species. Dense patches of the other two corals are less-frequently reported. For instance, dense aggregations of *Dentomuricea* aff. *meteor* have only been recorded in 5 areas so far, with the largest and most structurally complex populations observed in Cavala and Mar da Prata seamounts.

Another octocoral-dominated community found on the upper slopes of several seamounts corresponds to that formed by the bubblegum coral *Paragorgia johnsoni,* generally accompanied by a high number of small soft corals (e.g. P*seudoanthomastus* cf. *agaricus*) and cup corals (e.g. *Leptopsammia formosa*). Very large colonies of this gorgonian species have been observed in several seamounts of the MAR, especially in Beta and the Western ridge of the Gigante Seamount Complex (Figure 35). Also very characteristic in the MAR is the association that is formed by the octocoral *Pleurocorallium johnsoni* and the yellow laminate sponge cf. *Poecillastra compressa,* especially on the upper slopes between 500 and 700 m depth. This community is generally found on clean hard surfaces that show some inclination, especially on basaltic rock, although it has also been reported developing on lava balloons. A bit further deep (600-800 m), some dense aggregations of the primnoids *Narella bellissima* and *Narella versluysi* can become very common, sometimes covering extensive areas. This is the case of Cavalo and Formigas seamounts (Figure 36d), where very dense patches, mostly dominated by *N. versluysi*, have been observed for hundreds of meters. The number of species associated with this community is large, and includes not only sessile but also mobile fauna. Other less-common octocoral dominated communities correspond to those characterized by the primnoids *Candidella imbricata* and *Paracalyptrophora josephinae*. The former tends to generate extremely dense patches over boulders, with high numbers of associated species, with a limited spatial coverage. The latter has only been observed forming dense aggregations in Voador seamount, with most colonies of a great size and showing little signs of fishing impacts. It was always accompanied by a hydrozoan species, most likely *Lytocarpia myriophyllum*.

The deepest areas explored (1000-1400 m), generally at the base of the seamounts, are also home to another highly diverse mixed coral community, which includes several species of Plexauridae corals, black corals and bamboo corals. The densities of each species within this community is very variable, but the densest aggregations have been reported from a deep ridge east of Gigante and in Formigas seamount (Figure 36e). Some of the common fauna commonly observed include the Antipatharians *Leipathes expansa*, the bamboo corals *Lepidisis* sp, *Keratoisis* sp. and *Acanella arbuscula* and the octocorals *Iridogorgia* sp, *Chrysogorgia* sp, *Hemicorallium tricolor* and *Paramuricea* sp., among others. The inaccessibility of this community and the lack of samples until recently implies that there are still some gaps in the identification of some species, especially those belonging to the Plexauridae family. Further efforts will be made to better understand the full diversity of this complex community.

Besides the octocoral-dominated communities, other cnidarian species are also responsible for dense aggregations that lead to the development of structurally complex communities. This is the case of the hydrozoan of the Stylasteridae family *Errina dabneyi* (Figure 36f), a (likely) endemic species of the Azores archipelago that has been observed forming highly dense patches in areas around islands of the central group, namely Capelinhos (W faial) and the small seamounts southeast of Pico. The fauna associated to these stylasterid aggregations is similar to that found on seamount summits, although in lower densities, with the four main octocorals listed previously (*V. flagellum*, *C. verticillata*, *A. hirsuta* and *D. meteor*). Although scleractinian corals are not very conspicuous in the Azores, at least in terms of biomass, some species identified in the images can be considered characteristic of several benthic communities. This is mainly the case of the azooxanthellate scleractinian of the family Dendrophylliidae *Eguchipsammia* cf. *cornucopia*, which is known to form reefs in at least two areas in the central group (Condor and SE Pico), besides the first record discovered in the Faial-Pico Channel (Tempera et al., 2015).

At least six different sponge-dominated communities have been identified in the Azores deep-sea so far. Most seamounts of the MAR host aggregations of lithistid sponges, where the giant sponge cf. *Characella pachastrelloides* is the most conspicuous due to its large sizes. This sponge is generally found in association with other large lithistid Porifera in large rocky outcrops or on the slopes of the seamounts, generally below 600 m depth. Some of these species include *Petrosia crassa*, *Leiodermatium pfeifferae*, *Neophrisospongia nolitangiere* and *Macandrewia azorica* (Figure 36g), among others. When the mother rock has a basaltic origin (darker coloration), the sponge fauna shifts to a slightly different species composition, with a dominance encrusting sponges for which identification to species level for many of them has not yet been possible. Within those areas, the most common large porifera are *Craniella longipilis* and *Haliclona magna*, sometimes reaching impressive sizes. In the summit of some seamounts, dense patches of the glass sponge *Asconema* have been observed, generally covering small areas. This Rossellidae sponge tends to appear as an accompanying species in other communities, and such aggregations seem to be rare and have only reported in three seamounts so far: Beta, Sarda and Condor. Another hexactinellid sponge that can also form dense aggregations in the Azores deep sea is the tubular *Pheronema carpenter*i (Figure 36h). This species is commonly observed on soft or mixed substrates in deeper areas, usually in seamounts or slopes characterized by high rates of sediment deposition. Some of the densest aggregations have been observed in Condor seamount and on the slopes of Pico island. The remaining sponge communities found in the Azores are characterized by small pedunculate sponges (*Hyalonema* sp. and *Stylocordyla pellita*; Figure 36i), which develop over soft sediments in some of the deepest areas investigated (1000 m). Their distribution is so far restricted to Formigas and Sarda seamounts, but this could change when the base of other seamounts is explored.

Finally, besides the coral- and sponge-dominated communities, fauna from other phyla have also been identified as characteristic species in other benthic communities, including some aggregations of echinoderms such as sea urchins or sea stars. Especially relevant is the case of the community characterized by the deep-sea oyster cf. *Neopycnodonte zibrowii* and the crinoid cf. *Cyathidium foresti* on vertical walls (Figure 36j). This community, found always in seamounts and slopes close to the islands, is considered a 'living-fossil community' since it has most likely survived the Cretaceous/Palaeogene mass extinction and the whole of the Cenozoic (Wisshak et al., 2009). Another important aggregation found in many areas of the Azores is that formed by the xenophyophore cf. *Syringammina fragilissima*, wich develops in soft bottoms of mud/sand at the base of the seamounts. It is usually found past 1000 m depth, although it has been observed up to 700 m depth in the slopes of Pico island. The densities of this foraminifera are generally low, but it extends for large areas when present.

As it can be observed in Figure 35, the spatial coverage of the video recordings evaluated for this report is relatively large, so the characterization of deep-sea benthic communities can be considered representative of the depth range explored. However, further efforts are still required understand how benthic diversity is organized along the depth gradient below 800 m depth. The number of seamounts for which video data is available past those depths is still limited, with only a few representatives so far. Furthermore, some knowledge gaps still exist around the islands that make up the western group, for which no information is currently available, as well as those seamounts and ridges located on the Mid-Atlantic ridge north of Oscar seamount (39º 35' N).

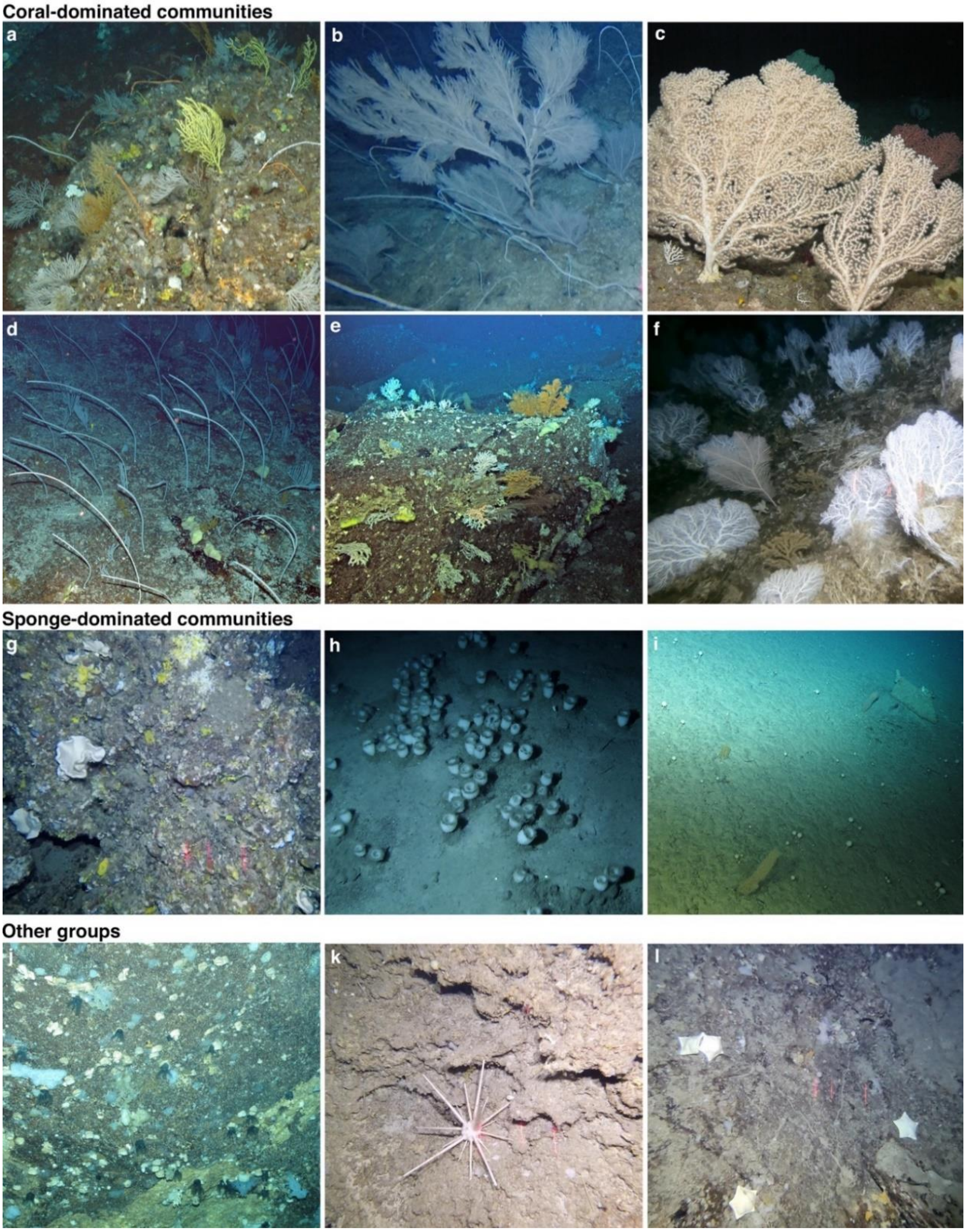

Figure 36. Some examples of benthic communities identified in the Azores deep-sea. (a) Very diverse patch on a large boulder with the octocorals Viminella flagellum, Acanthogorgia cf. hirsuta, Dentomuricea aff. meteor in Gigante seamount. (b) Large colonies of Callogorgia verticillata and Viminella flagellum observed in Picoto seamount. (c) A dense aggregation of the hydroid coral Errina dabneyi in Capelinhos. (d) Large Paragorgia johnsoni colonies found on the slopes of the western ridge, in the Gigante Seamount Complex. (e) Dense aggregation of the Primnoid Narella versluysi with a few other corals and glass sponges in Formigas seamount. (f) Aspect of a large rocky outcrops colonized by cold-water corals, including several species of scleractinians, octocorals, black corals and bamboo corals below 1000 m depth in Formigas seamount. (g) Some of the various species of Porifera observed on large rocky outcrops and vertical walls in Voador seamount. (h) Aggregation of the hexactinellid Pheronema carpenteri in Condor seamount. (i) Dense aggregation of the pedunculate sponge Stylocordyla pellita. (j) Ancient community found in vertical walls with cf. Cyathidium foresti. (k) Bare outcropping rocks with the long-spine sea urchin cf. Cidaris cidaris in Ferradura seamount. (l). Some sea stars of the family Goniasteridae in Oscar seamount. The complete list of benthic communities is provided in Table 4. a,c © Luso ROV, EMEPC; b,f,g,k,l © Drift cam, IMAR/Okenaos UAç; d,e,j © Liropu ROV, IEO; h © Hopper tow-cam, NIOZ.

Table 4. Summary of the main benthic communities that have been identified so far in each of the features (ridges -Rg- , seamounts –Smt- or slopes -Sl-) visually investigated in the Azores EEZ. The species names given in each category represent the most conspicuous/abundant organism, and does not imply the lack of other associated/structural fauna.

	Mid-Atlantic Ridge																Central									Eastern		
Benthic communities	Oscar	Gigante	127	Western Rg.	Rg. E. Gigante	A6	Ferradura	Cavala	Beta	Picoto	Alfa	Voador	Monte Alto	A3	Sarda	Cavalo	Condor	Capelinhos	S. Mateus smt	Sl. Pico	Sl. S. Jorge	SE of Pico	S. Jorge de	Sl. Terceira	D. João Castro	Alcatraz	Mar da Plata	Formigas
Coral-dominated communities																												
Mixed coral gardens with the octocorals *V. flagellum*, *C. verticillata*, *A. hirsuta*, *D. meteor*																												
Monospecific or dominated by *Viminella flagellum*	•	•	•	•		•	•	•		•	•	•	•	•	•		•						•	•	•	•		
Monospecific or dominated by *Callogorgia verticillata*	•						•			•		•	•		•		•	•				•	•		•			
Monospecific or dominated by *Acanthogorgia* cf. *hirsuta*	•	•		•												•	•	•				•						
Monospecific or dominated by *Dentomuricea* aff. *meteor*		•						•									•					•					•	
Coral gardens with *Paragorgia johnsoni* & *Pseudoanthomastus* cf.*agaricus*		•		•			•	•	•		•				•									•				
Coral gardens with *Pleurocorallium johnsoni* & cf. *Poecillastra compressa*	•	•	•	•		•		•		•	•				•													
Coral gardens with *Narella versluysi* & *Narella bellissima*	•	•				•	•		•						•	•			•				•					•
Coral gardens with *Candidella imbricata*		•										•			•		•											•
Coral gardens with *Paracalyptrophora josephinae* & cf. *Lytocarpia myriophyllum*												•																
Coral gardens with *Errina dabneyi*																		•				•						
Fields of *Acanella arbuscula*																							•					•
Fields of large hydrozoans												•					•	•										
Fields of soft corals																		•										
Fields of *Leptopsammia formosa*	•																			•				•				
Fields of *Crypthellia vascomarquesi*																							•					•
Reefs of *Eguchipsammia* cf. *cornucopia*																	•					•						
Mixed coral gardens with several Antipatharians, bamboo corals and Plexauridae					•																							•
Vertical walls; *Leiopathes expansa*, *Lophelia pertusa*, *Dendrophyllia cornigera* & *Farrea occa*																			•	•								
Aggregations of *Flabellum* spp.	•		•	•		•	•						•				•											
Deposits of coral rubble	•	•		•		•	•	•	•	•	•	•		•	•			•	•	•		•	•					•
Sponge-dominated communities																												
Agg. of lithistid Porifera *C. pachastrelloides, P. crassa, Leiodermatium & N. nolitangiere*		•	•	•				•	•			•	•	•	•		•		•	•	•	•		•	•	•	•	
Aggregations of encrusting and other large lithistid Porifera on basaltic rock	•	•	•	•		•	•	•		•	•	•	•	•		•			•									
Fields of *Pheronema carpenteri*		•			•	•									•		•		•	•			•	•				•
Fields of *Asconema* sp.									•						•		•											
Fields of *Stylacordilla pellita*																												•
Fields of *Hyalonema* sp.															•													
Other groups																												
Aggregations of *Cidaris cidaris*		•	•				•	•																				•
Fields of cf. *Syringammina fragilissima*															•		•		•	•			•	•				
Vertical walls with cf. *Neopycnodonte zibrowii* & cf. *Cyathidium foresti*																			•	•	•							•
Aggregations of Goniasteridae sp.	•																											

5.2. Defining what constitute a VME in the Azores using expert judgement

Recognizing the vulnerability of deep-sea biodiversity, the United Nations General Assembly (UNGA) called upon States and Regional Fisheries Management Organizations (RFMOs) to identify areas where vulnerable marine ecosystems (VME) occur, or are likely to occur, and to prevent significant adverse impacts (UNGA, 2006). The Food and Agricultural Organization (FAO) of the United Nations subsequently developed criteria for defining what constitutes (FAO, 2009; 2016):

- ***Uniqueness or rarity:*** an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include: habitats that contain endemic species habitats of rare, threatened or endangered species that occur only in discrete areas nurseries or discrete feeding, breeding, or spawning areas;
- ***Functional significance of the habitat:*** discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species;
- ***Fragility:*** an ecosystem that is highly susceptible to degradation by anthropogenic activities;
- ***Life-history traits of component species that make recovery difficult:*** ecosystems that are characterised by populations or assemblages of species with one or more of the following characteristics: slow growth rates, late age of maturity, low or unpredictable recruitment, and/or long-lived;
- ***Structural complexity:*** an ecosystem that is characterised by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.

These criteria may apply to a wide variety of habitats and ecosystems of the deep-sea (e.g. hydrothermal vents, seamounts or cold seeps). Whilst significant steps have been made to map and protect VMEs in the high-seas areas in general (e.g. Portela et al., 2010) and in the high-seas areas regulated by RFMOs (e.g. Durán-Muñoz et al., 2012), progress has been inconsistent or incomplete, mainly in national waters (Durán-Muñoz and Sayago-Gil, 2011; FAO, 2016). Vulnerable marine ecosystems have been identified based on the occurrence of indicator taxa such as stony or gorgonian corals, or sponges, and are therefore best identified using high-quality underwater imagery, allowing accurate and quantitative description of community composition and associated fauna (e.g., ICES, 2016, 2017).

The underwater features described above were assessed against each of the five FAO criteria for defining what constitute a VME using expert judgement. Thirteen features out of the 28 features visually evaluated were identified as priority areas for conservation (Table 5). These features were generally characterized by great diversity of species and biological communities, with unique characteristics in terms of composition of endemic, rare or threatened species (FAO criteria 1), and/or communities composed of tall, and arborescent species that provide complex habitat for other species (FAO criteria 5). Fragility of the habitat-forming species (FAO criteria 3) was based on evidence of vulnerability to physical contact, such as accidental capture during long-line fishing (based on Sampaio et al., 2012; COLETA database), and the capacity of species for retraction, retention or re-growth or natural protection in some way (e.g. vertical walls or overhangs not accessible by fishing or located below maximum longline fishing depths). In most instances, large organisms with complex 3D morphologies, e.g. octocorals such as *Callogorgia verticillata*, *Paracalypthrophora josephinae*, *Paragorgia jonhsoni* and black coral *Leiopathes* spp., are also more susceptible to longline fishing, with their removal significantly reducing habitat complexity of the underwater features where they occur.

In general, there was limited information to assess the life history and functional significance of the species/communities (FAO criteria 2 and 4 respectively) due to major knowledge gaps on species reproductive cycles, growth rates, reproductive output, larvae biology and dispersal, recruitment and their role in the functioning of the ecosystems such as nursery areas for other species, nutrient regeneration, and carbon remineralization and sequestration. When available, information on life history traits for closely related species or same taxa family was used as a proxy to score for that criteria, based on the assumption that these traits are phylogenetically conserved (Kraft et al., 2007). As for functional significance of the habitat, there is information regarding fish and sharks' aggregations in or close to coral gardens, for example the deep-water shark *Dalathias licha* and the fish *Hoplostethus mediterraneus* in Gigante seamount. However, it is difficult to infer a direct link between habitat forming species such as corals or sponges and their role as nursery grounds, especially based on observed adult fish and shark species. Because of limited knowledge, in most cases it was assumed that those features that presented highest diversity of species and communities had a potentially higher functional significance. This is based on studies that show a direct relationship between biodiversity and ecosystem functioning for deep-sea ecosystems (Snelgrove et al., 2014; Zeppilli et al., 2016) and how habitat heterogeneity increases the number of niches for associated species, ecological interactions, and food web complexity (Buhl-Mortensen et al., 2010; Zeppilli et al., 2016). Though, as new scientific knowledge is gathered in the future, a better assessment of these criteria will be possible.

Table 5. Assessment of underwater features against five criteria for defining what constitutes a Vulnerable Marine Ecosystem (FAO, 2009). Low fit to a criterion is coloured in dark-blue, medium light-blue, high in pink, and very high in red. Features identified as VMEs are highlighted in bold and grey.

Area	Underwater Feature	Unique	Functional	Fragility	Life history	Structural	General description
MAR	***Oscar***						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of benthic communities. Dense coral gardens dominated by octocorals, particularly *Callogorgia verticillata* with large colonies (~1.5 m height) not seen in many other areas. *C. verticillata* has low growth rates and low reproductive output (Carreiro-Silva, unpub. data) and is highly susceptible to fishing based on fisheries bycatch data (Sampaio et al., 2012).
	Gigante						FAO listed VME hydrothermal vent, presence of endemic species *Dentomuricea* aff. *meteor*. High diversity of species and communities. Hydrothermal vent Luso. Dense coral gardens dominated by octocorals, particularly *Paragogia johnsoni* with large colonies (~1.5 m height) and endemic *D. meteor*. *P. johnsoni* highly susceptible to fishing based on damaged colonies observed in video surveys. *Paragorgia* species have high longevity (~ 100 years) and slow growth rates (Sherwood & Edinger, 2009).
	127						Low abundance of habitat-building corals and sponges; hard substrates dominated by sponges and widespread octocoral *Viminella flagellum*.
	Western ridge						Species with mixed amphi-Atlantic and Atlanto-Mediterranean distribution. Populations of CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*. Dense *Paragorgia johnsoni* gardens with some of the largest colonies recorded so far showing little impact from fishing.
	Ridge east of Gigante						CITES listed black coral species *Leiopathes*. Diverse coral communities composed by large structuring species such as bamboo corals *(Lepidisis* and *Keratoisis)* and the black coral *Leiopathes* spp. These species are characterized by low growth rates, high longevities (centuries to millennia for bamboo corals and black corals respectively, Andrews et al., 2009; Carreiro-Silva et al., 2013). Presence of several corals of the family Plexauridae, not seen elsewhere and that may be new to Science. Communities naturally protected from fishing impacts because of great depths (below 1000 m).
	A6						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of coral and sponge species. Communities with a dominance of sponges species.
	Ferradura						CITES listed black coral species *Leiopathes*. Dense coral gardens dominated by octocorals, with some evidence of fishing impact.
	Cavala						Presence of endemic species *Dentomuricea* aff. *meteor*. High diversity of species and communities. Dense coral gardens dominated by *D. meteor,* one of the densest recorded in the Azores so far. Presence of large *Paragorgia johnsoni, Pleurocorallium johnsoni* and *Paracalypthrophora josephinae*. Species highly susceptible to fishing based on bycatch data (Sampaio et al., 2012) or evidence of broken colonies in video surveys. Structural species characterized by slow growth and low reproductive output (Sherwood and Edinger, 2009; Perrin et al., 2015, Carreiro-Silva, unpub. data).
	Beta						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Dense and diverse coral gardens dominated by large octocorals and sponge aggregations. Dense *Paragorgia johnsoni* gardens with some very large colonies. Communities generally well preserved showing little impact from fishing.
	Picoto						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of benthic communities. Coral gardens dominated by the octocorals *Viminella flagellum* and *Callogorgia verticillata,* with some very tall colonies that showed little impact from fishing.

Area	Underwater Feature	*Unique*	*Functional*	*Fragility*	*Life history*	*Structural*	General description
	Alfa						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of benthic communities and overall low densities of corals and sponges, generally of small sized specimens. Evidence of fishing impacts.
	Voador						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of species and communities. Densest coral gardens of the octocoral *Paracalypthrophora josephinae* observed in the Azores so far, with the presence of tall colonies. Species highly susceptible to fishing based on bycatch data (Sampaio et al., 2012); and low growth rates and reproductive output (Carreiro-Silva, unpub. data). Dense aggregation of *Candidella imbricata* at shallow depths.
	Monte Alto						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low number of benthic communities, with low densities overall.
	A3						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of coral and sponge species and communities. Mostly species of small size.
	Sarda						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High number of benthic communities observed. Diverse coral and sponge assemblages, although some are very localized in space. Presence of large colonies of *Paragorgia johnsoni* and *Callogorgia verticillata*, which are slow growing, long lived species susceptible to fishing (Sampaio et al., 2012).
	Cavalo						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of species and communities. Dense coral gardens dominated by octocorals *Narella versluysi* and *N. bellissima,* largest aggregations recorded in the Azores so far. Presence of large colonies of the octocorals *Paragorgia johnsoni* and *Callogorgia verticillata*, which are slow growing, long-lived species susceptible to fishing (Sampaio et al., 2012).
Central	***Condor***						Populations of endemic species *Dentomuricea* aff. *meteor* and CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*. High diversity of species and communities. Mixed coral gardens composed of several octocoral species and sponge aggregations. Slow growing, long-lived species susceptible to fishing based on bycatch data (Sampaio et al., 2012). Reefs of *E. cornucopia*, a species not known to form reefs elsewhere in the Atlantic and representing a potential relict species from geological past (Tempera et al., 2015). Seamount important for scientific research (Morato et al., 2010).
	Capelinhos						Populations of endemic octocoral species *Dentomuricea* aff. *meteor* and stylasterid *Errina dabneyi* and CITES listed black corals *Antipathella subpinnata*, *Leiopathes* sp. and stylasterid *Errina dabneyi*. High diversity of species and communities. Dense coral gardens formed by octocorals, black corals and stylasterids. Dense mesophotic coral gardens dominated by the soft coral cf. *Alcyonium* sp. Presence of large colonies of millennia-old *Leiopathes* sp. Evidence of shark aggregations. Little impact from fishing due to absence of long-line fishing. Area important for geology and scientific research.
	Baixo São Mateus						Presence of "fossil community" composed of long-lived oysters and crinoids (cf. *Neopycnodonte zibrowii* and cf. *Cyathidium foresti*) found only in the Azores. Low diversity of species and communities in vertical walls, naturally protected from fishing. Presence of large sponges cf. *Characella pachastrelloides*. Presence of numerous fishing lines indicating high pressure from fishing.
	Slopes of Pico						Presence of "fossil community" composed of long-lived oysters and cirripeds (cf. *Neopycnodonte zibrowii* and cf. *Cyathidium foresti*) found only in the Azores. High diversity of corals and sponges but sparsely occurring

Area	Underwater Feature	Unique	Functional	Fragility	Life history	Structural	General description
							on large boulders and mostly of most of small size. Communities in vertical walls naturally protected from fishing.
	SE of Pico						Presence of endemic species *Dentomuricea* aff. *meteor* and CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*, black coral *Antipathella subpinnata* and stylasterid *Errina dabneyi*. High diversity of species and communities. Dense coral gardens dominated by octocorals and sponges. Species with low growth and reproductive output vulnerable to fishing (Sampaio et al., 2012). Reefs of *E. cornucopia,* a species not known to form reefs elsewhere in the Atlantic and representing a potential relict species from geological past (Tempera et al., 2015).
	Slopes of São Jorge						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of corals and sponges and mostly of small size. Communities in vertical walls naturally protected from fishing.
	São Jorge de Fora						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Although the number of communities identified is high, they are very localized in space and species showing with low densities overall. Presence of *Callogorgia verticillata*, slow growing, long-lived species susceptible to fishing (Sampaio et al., 2012).
	Slopes of Terceira						Species with amphi-Atlantic or Atlanto-Mediterranean distribution Low diversity of species and communities, although presence of a few large colonies of *Paragorgia johnsoni* and *Pleurocorallium johnsoni*, showing impacts from fishing.
	Dom João de Castro						FAO listed VME hydrothermal vent, species with amphi-Atlantic or Atlanto-Mediterranean distribution. Dense coral gardens dominated by octocorals, particularly *Callogorgia verticillata,* with the presence of many large colonies. Few signs of fishing impacts.
Eastern	Alcatraz						Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of species and communities. Presence of large sponges *Characella pachastrelloides*. Evidence of fishing impacts.
	Mar da Prata						Presence of endemic species *Dentomuricea* aff. *meteor*. Dense coral gardens dominated by octocorals and diverse sponge aggregations but covering a small area. Evidence of fishing impacts..
	Formigas						Presence of CITES listed black coral *Leiopathes* sp. High diversity of species and communities. Dense coral gardens dominated by octocorals and black corals, and diverse sponge aggregations. Millennia-old black coral *Leiopathes*. Communities generally well preserved showing little impacts from fishing.

The MAR region included the greatest number of underwater features that fit the FAO criteria for VME (Table 5). A high number of distinctive communities was found for most of these features, composed of tall arborescent colonies of long-lived, slow growing species with low reproductive output (e.g. *Paragorgia johnsoni*, *Pleurocorallium johnsoni*, *Callogorgia verticillata*, *Paracalypthrophora josephinae*, *Keratoisis*, *Lepidisis*, *Leiopathes* sp.: Andrews et al., 2009; Sherwood & Edinger, 2009; Carreiro-Silva et al., 2013; Perrin et al., 2015), and highly susceptible to the impact of fishing (Sampaio et al., 2012). Notable in this region was also the newly discovered hydrothermal vent field Luso, which differs considerably from other known hydrothermal fields along the MAR. In the case of the Ridge east of Gigante, important communities were recorded in deep areas naturally protected from long-line fishing. However, presence of millennia-old black corals and century-old bamboo corals not found in shallower areas, justifies their inclusion as priority areas for conservation. In addition, in these deeper less explored areas, several unidentified corals of the family Plexauridae were recorded and may be new to science.

In the Central group, the Condor seamount was distinguished by a high number of dissimilar coral and sponge communities over a wide bathymetric range (Table 4) further emphasizing the importance of this seamount for scientific research (Morato et al., 2010). Dom João de Castro seamount was notable for the very dense *Callogorgia verticillata* gardens in deep areas (300-400 m) and hydrothermal vents at shallow depths (20 m depth). Underwater features of SE of Pico and Capelinhos, were also particularly diverse and unique, with dense communities of the endemic and fragile stylasterid species *Errina dabneyi*, not commonly found in other areas. The SE Pico was also distinguished by an extensive reef formed by the scleractinian *Eguchipsammia* cf. *cornucopia*, a species not known to form reefs elsewhere in the Atlantic and representing a potential relict species from geological past (Tempera et al., 2015). In Capelinhos, dense coral gardens of the black coral *Antipathella subpinnata* were associated with millennia-old black coral *Leiopathes* sp. Although not recorded in our surveys, well-developed reefs of *Lophelia pertusa* are also reported for Capelinhos (Rebikoff-Niggeler Foundation, unpublished data), further highlighting the high diversity of communities of this area. In the Eastern group, Formigas was particularly diverse, with well-preserved communities showing little impact from fishing and presence of several large colonies of *Leiopathes* sp.

5.3. Potential Vulnerable Marine Ecosystems identified in the Azores deep-sea

Based on the assessment described above, eleven large areas fitting the vulnerable marine ecosystem were identified (Figure 37), consisting of 3 portion of the MAR (Western ridge, Ridge east of Gigante, Cavalo) and eight seamounts (Oscar, Gigante, Cavala, Beta, Voador, Condor, D. João de Castro, and Formigas). The deep-sea around Capelinhos (Faial island) and SE Pico were also considered vulnerable marine ecosystem but were not included in this list since they are located in the coastal areas (within 6nm from shore) and therefore outside the deep-sea spatial planning area. A contour of the all areas was computed using the best available bathymetry data. ***<u>The areas identified here as potential VMEs should be given high priority in the design of a network of Marine Protected Areas in the Azores</u>***. However, it should be noticed that the limited knowledge on deep-sea benthic communities in the Azores may hamper the proper identification of VMEs. Therefore, continued scientific research is necessary to better understand the distribution, structural and functional role of deep-sea benthic communities and inform adaptive management and conservation policies.

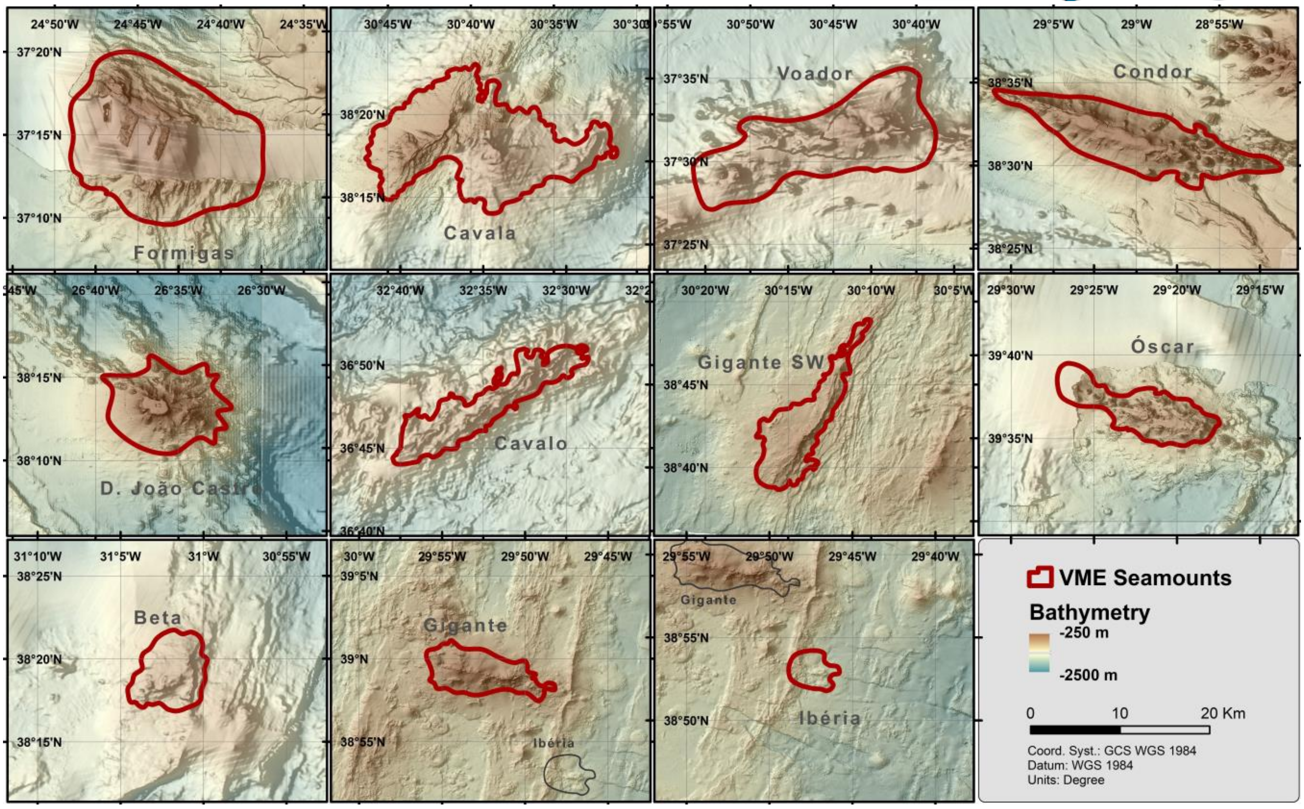

Figure 37. Underwater features considered as potential Vulnerable Marine Ecosystem (FAO, 2009) in the Azores.

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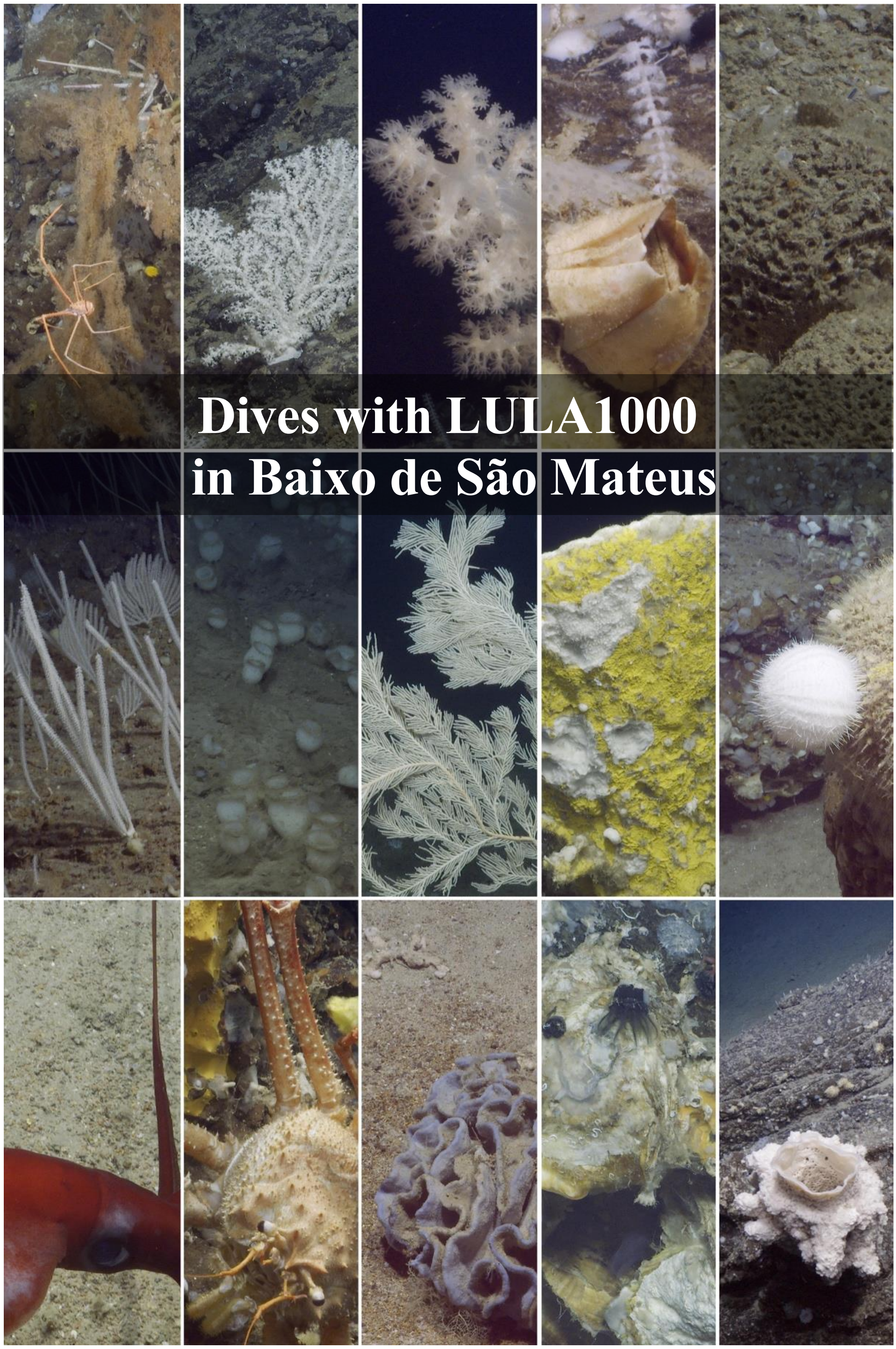
Deep-sea benthic communities inhabiting various geomorphological features in the Azores

Dives with LULA1000 in Baixo de São Mateus



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Executive summary

In order to comply with the provisions of the cooperation protocol between IMAR and the Blue Ocean Foundation, namely Clause Six, (c) *submission to the Blue Ocean Foundation of the Report with technical description of dives made with LULA1000 submersible (Rebikoff-Niggeler Foundation) including positioning in GIS format, dive time, route taken, technical description of the operation, etc., and recommendations for the protection of coral gardens and sponge grounds identified in the areas visited*, we have prepared the following report that is briefly summarized here.

Background

Deep-sea benthic ecosystems form complex three-dimensional structural habitats, supporting high biodiversity. Knowledge of the occurrence and distribution of these communities is of paramount importance to inform deep-sea management and conservation. In recent years, large efforts have been placed in characterizing and mapping deep-sea benthic communities inhabiting geomorphological features in the Azores using video platforms, such as commercial Remotely Operated Vehicles (ROVs), towed cameras and drop-down camera systems. Manned submersibles also represent a powerful tool for deep-sea exploration, offering a wider perception of the environment, they can generate better quality footage for science and outreach activities, with high definition close-ups that can help the identification of megafaunal species and associated macrofauna, and the possibility of exploring areas with high relief, such as steep slopes and vertical walls.

Baixo de São Mateus is known for its historical importance as a fishing ground south of Pico Island. Fisheries bycatch information suggests that this seamount may host important deep-sea benthic communities. However, Baixo São Mateus has never been explored with video surveying techniques. By taking advantage of the collaboration with the Fundação Rebikoff-Niggeler (FRN) and the use their submersible LULA1000, based in the harbor of Horta (Faial), we aimed to explore the never surveyed seamount ridge *Baixo de São Mateus*. The main objective of this survey was to evaluate if this area may fit the FAO criteria that defines what constitutes a Vulnerable Marine Ecosystem. Namely, we aimed to:

1. characterize the diversity and spatial distribution patterns of benthic communities and commercial fishes in this important fishing ground;
2. document potential fishing impacts on the main structuring species that conform the different benthic communities.

Deep-sea benthic communities in Baixo de São Mateus

Overall, approximately 3.7 linear kilometers of seafloor were covered during the two exploratory dives carried out in the southern flank of *Baixo de São Mateus*. A total of seven benthic communities were identified, showing a clear bathymetric zonation. The deepest areas explored (900-1000 m) corresponded to flat soft bottoms, where Foraminifera of the species *Syringammina fragilissima* were commonly observed. As soon as the rock began to outcrop, the diversity of benthic species increased exponentially, especially in vertical or very slopping walls. At the base of the slope, colonies of the black coral *Leiopathes expansa* were identified, surrounded by scleractinian corals of the species *Lophelia pertusa* and *Dendrophyllia cornigera*, as well as the glass sponge *Farrea occa*. Soft bottom patches around these rocky outcrops were colonized by aggregations of the glass sponge *Pheronema carpenteri*. Further up along the slope, the association between the primnoids *Narella bellissima* and *Narella verluysi* became common, with dense coral gardens at 750 m depth. Above 700 m depth, the rock experienced a clear change towards a sponge-dominated community, with giant sponges of the species cf. *Characella pachastrelloides,* among many others. At those depths, some vertical walls were colonized by the living fossil community composed by the oyster *Neopycnodonte zibrowii* and the crinoid *Cyathidium foresti*. Remnants of longline fishing gears (e.g. ropes and monofilament lines) were recorded during the two dives, with several broken or damaged colonies of corals and sponges observed.

Assessment against the VME criteria

The seamount ridge *Baixo de São Mateus* was assessed against each of the five FAO criteria for defining what constitute a VME using expert judgement.

- Uniqueness or rarity: No special rare or unique occurrences. Presence of "living fossil community" composed of long-lived oysters and crinoids (*Neopycnodonte zibrowii* and *Cyathidium foresti*) only reported for the Azores region so far. Some living colonies of the cold-water coral *Lophelia pertusa*, not a common sighting. Black coral *Leiopathes expansa* listed as a VME indicator species and CITES protected.
- Functional significance: Overall, low diversity of coral- and sponge-dominated communities.
- Fragility: Presence of numerous fishing lines along the dives, but low number of visibly damaged coral and sponge species.
- Life-history traits: Most long-lived species not unique and in low numbers. Black coral *L. expansa* with life spans of several millennia and low growth rates. Large colonies of the octocoral *Callogorgia verticillata* likely several centuries old.
- Structural complexity: Overall, low density and small size of habitat-forming corals and sponges, although locally there are some very dense patches of primnoid corals *Narella* spp. and some large aggregations of the glass sponge *Pheronema carpenteri*.

Management recommendations

Based on the assessment described above, the seamount ridge ***Baixo de São Mateus* does not fit the FAO criteria to be considered a VME** and thus there is no sufficient scientific information to support this area as high priority for conservation in the Azores. Despite the presence of some long-lived species, there was an overall low number of species and communities and in low densities, when compared to other geomorphological features of the Azores region. *Baixo São Mateus* is an important fishing ground in the Azores. The low natural diversity of the benthic communities observed may suggest that existing fishing pressures in *Baixo São Mateus* will likely not have produced significant adverse impacts in the existing benthic living communities. However, it should be noticed that the present assessment is based only on two video transects, which covered a limited area of the seamount ridge. It is thus possible that we may have missed some important communities or areas with higher species diversity or other large structuring species. Therefore, continued scientific research is necessary to better understand the distribution of species, as well as the structural and functional role of such deep-sea benthic communities to better define adaptive management and conservation strategies.

Dives with LULA1000 in Baixo de São Mateus

August 2019

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1. Introduction

Deep-sea benthic ecosystems form complex three-dimensional structural habitats, supporting high biodiversity by providing refuge, feeding, and spawning and nursery areas for a wide range of organisms, including socio-economically important deep-sea fish species (Braga-Henriques et al., 2011, 2012; Porteiro et al., 2013; Pham et al., 2015; Gomes-Pereira et al., 2017; Carreiro-Silva et al., 2017). Therefore, knowledge on the occurrence, distribution and ecological importance of deep-sea benthic communities inhabiting geomorphological features such as seamounts, island slopes and ridges is of paramount importance for informing deep-sea management and conservation.

This information has mostly been gathered using video platforms, such as commercial Remotely Operated Vehicles (ROVs), as well as towed and drift camera systems (see Deliverable 3). Unlike traditional video platforms, manned submersibles are not connected to a surface support ship via an umbilical cable, which could become entangled in complex reliefs. In general, these platforms offer direct *in-situ* observations, a wider perception of the environment, better quality footage for science and outreach, the possibility of very high definition close-ups to help species and associated macrofauna identification, and offer the possibility of exploring areas with high relief such as steep slopes and vertical walls. Vertical walls, defined as seabed structures with an angle above 70º, are common geological structures in the Azores, and are associated with the steep submarine morphology of island slopes and seamounts. Due to technical challenges posed by the use of traditional sampling techniques in such environments, vertical structures have been less surveyed than horizontal and sloping areas. Thus, manned submersibles are best suitable to study benthic communities dwelling on vertical walls and overhangs.

Baixo de São Mateus is known for its historical importance as a fishing ground south of Pico Island, mainly due to its proximity to a few fishing villages, where an intense whaling activity occurred during decades. In the last decade, observers onboard fishing vessels have collected a large number of records of deep-sea benthic species accidentally by-caught during commercial operation; data stored in the University of the Azores's biological reference collection COLETA. These records suggest that *Baixo São Mateus* may host important deep-sea benthic communities, mostly composed of *Callogorgia verticillata*, *Paracalypthrophora josephinae*, *Dendrophylia cornigera* and *Lophelia pertusa*. However, Baixo São Mateus has never been explored with video surveying techniques.

By taking advantage of the collaboration with the Fundação Rebikoff-Niggeler and the use their submersible LULA 1000, based in the harbour of Horta (Faial), we aimed to explore the never surveyed seamount ridge *Baixo de São Mateus* (Fig. 1). The submersible surveys of *Baixo de São Mateus* had a double objective. On the one hand, it aimed to evaluate if this area may fit the FAO criteria that define what constitutes a Vulnerable Marine Ecosystem, by characterizing the diversity and spatial distribution patterns of the main benthic communities that dwell on its slope, as well as document the fish fauna that can be observed in this important fishing ground. On the other hand, the survey aimed to document the potential fishing impacts on the sessile benthic megafauna (e.g. cold-water corals and sponges). The information collected here was used in the data-driven approach that developed systematic conservation planning scenarios to inform the establishment of a network of protected areas inside the Azores Exclusive Economic Zone (EEZ).

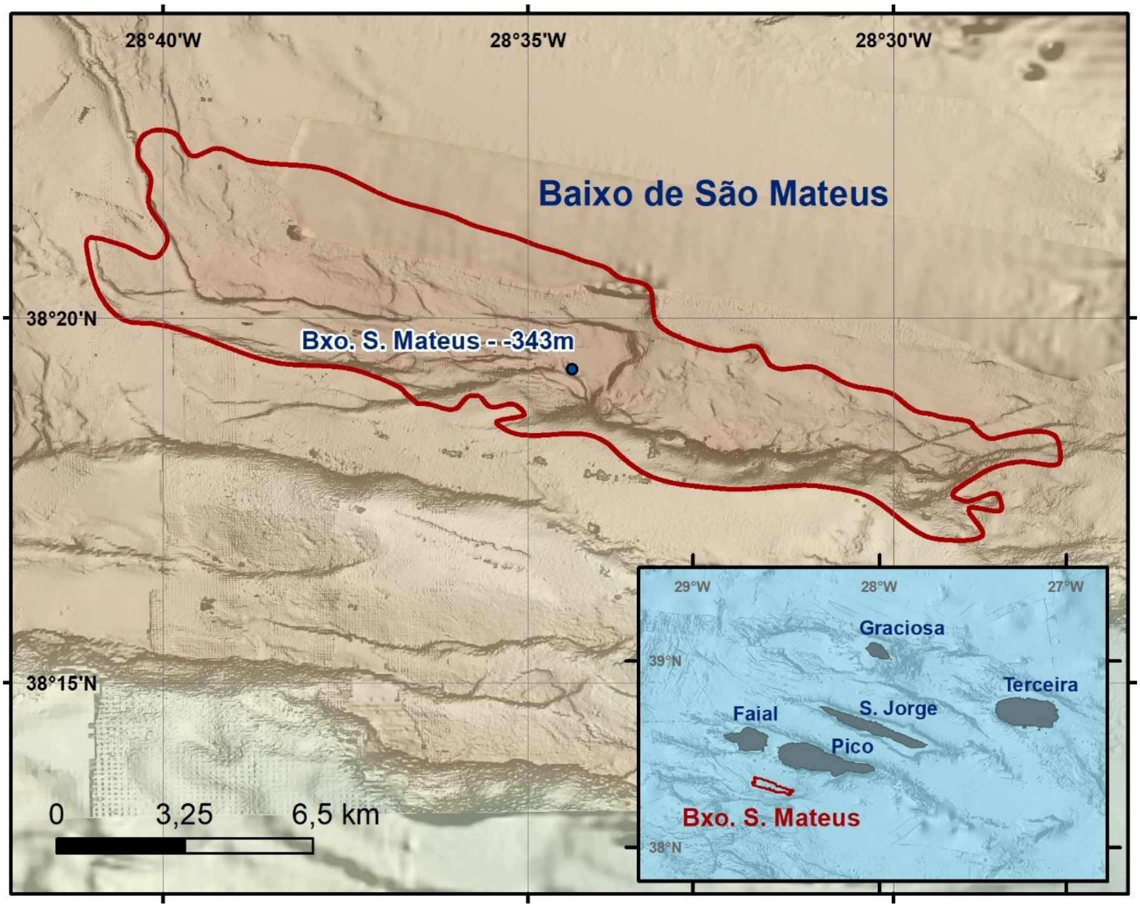

Figure 1. *Detailed underwater morphology and extent of Baixo de São Mateus ridge located south of Pico Island.*

2. Methodology

Dates: 13-14th August 2019
Chief scientist: Marina Carreiro-Silva
Vessel: Catamaran Ada Rebikoff
Platform: Submersible LULA1000 (DNV-GL/Hamburg, Fig. 2) owned and operated by the Rebikoff-Niggeler Foundation (https://www.rebikoff.org/submersible-lula-1000/). LULA1000 is 7.5 m in length and has the capacity to carry two pilots and one scientist up to a maximum of 1000 m depth. The underwater navigation system is composed by a USBL TrackLink 1500HA with transceiver e transponder TN1510AHR omni-directional, a horizontal sonar with 360° and Doppler Velocity Log. LULA1000 has a 150° spherical viewport (diameter: 1414mm) and is equipped with two video cameras 4K (Sony Alpha A II S/R and Sony Alpha A III R with lenses Sony PXW-X70) and a lighting system composed of 4 HMI 400W and 6 HMI 200W.

Figure 2. *LULA1000 submersible operated by the Niggeller-Rebikoff Foundation in front of Horta's harbour, in Faial Island (Azores).*

Two dives with the manned submersible LULA1000 were performed on the south-eastern flank of *Baixo de São Mateus*, located just 15 km south of Pico Island (Fig. 3). *Baixo de São Mateus* is an elongated seamount ridge that stretches around 20 km in length, with its shallowest points reaching depths of 340 m. The northern flank of the seamount has a gentle slope (mean of the 6.5º) elevating from 700 to 350 m, while the southern and south-eastern flanks have steep slopes (mean slope of 17.2º) with several areas of vertical walls, elevating from 1100 m to 350 m depth.

Both dives were performed in an area with steep slopes and near-vertical walls with the objective of characterizing the benthic communities inhabiting these less surveyed habitats and capturing the bathymetric zonation of deep-sea benthic communities along this geomorphological feature. Video transects were conducted from the deepest point at around 1000 m and reaching its flatter and shallowest point, close to 500 m depth (Table 1). The submersible followed a georeferenced path at a speed of 0.1–0.2 or 0.7–1.4 $m \cdot s^{-1}$ for near-vertical or less steep terrain, respectively, and with a field view of 0.5–3 m wide. Overall, approximately 3.7 linear kilometers of seafloor were covered in both dives, totaling 7 hours of video footage on the seabed (Table 1).

High-definition video footage was recorded using two 4K Sony cameras (see details above). The first camera was in a forward-looking position inside the submersible, while the second was in an oblique forward-looking position providing an overview of the seabed ahead. Videos were thoroughly analysed for the presence of three types of events: (1) invertebrate megafauna, (2) type of substratum, and (3) presence or fishing lines, marine litter and coral damage. Benthic observations consisted of sessile megafauna that were distinctly identifiable in the images (>5 cm, but mainly >15 cm). Close-up images of selected coral species were also performed for the characterization of associated macrofauna.

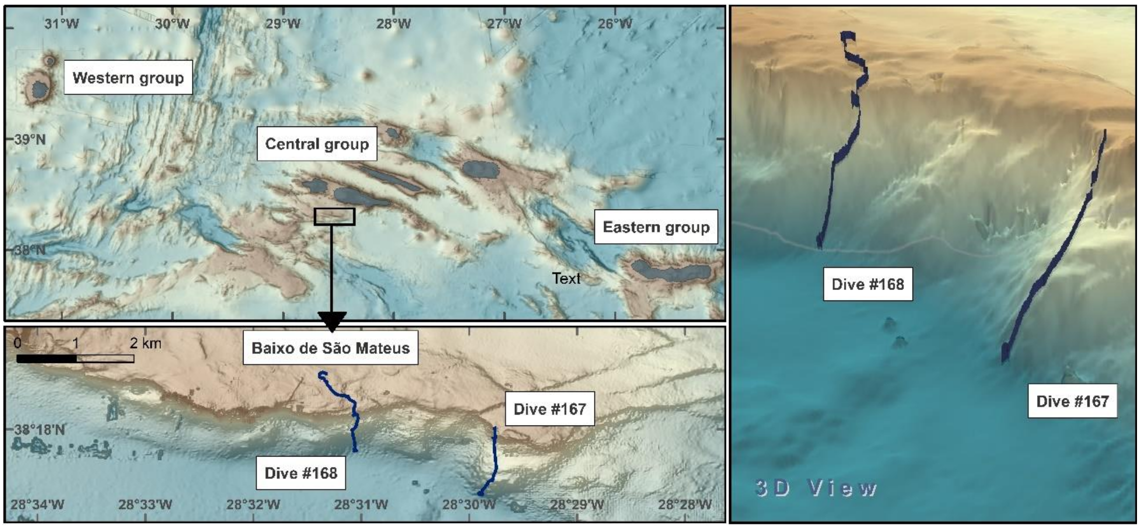

Figure 3. *Location of the two underwater dives carried out in southern flank of Baixo de São Mateus. The exact location of the start and end points of each dive is given in Table 1.*

Table 1. *Metadata of the two dives carried out by the submersible LULA1000 at Baixo de São Mateus seamount ridge.*

Dive	Date	Bottom time	Start Lat.	Start Lon.	End Lat.	End Lon.	Start depth	End depth	Dive length (m)
1	13/08/2019	02:48	38.2900	-28.4979	38.3001	-28.4960	963	496	1455
2	14/08/2019	04:12	38.2966	-28.5178	38.3086	-28.5221	965	493	2230

3. Characterization of benthic communities

Due to its close proximity to the island of Pico, the slopes of *Baixo de São Mateus* are of a sedimentary nature, with most of its rocky outcrops covered in a layer of mud and fine sand. As expected, an evident bathymetric zonation pattern regarding the distribution of the benthic communities was observed in both dives, which are described below.

Summary of Dive #1

LULA1000 dive #167, 13th August 2019

The submarine reached the seafloor at the very base of the slope at 13:17, seeing the seabed for the first time at a depth of 963 m (Fig. 3). The substrate was characterized by a mixture of coral rubble compacted by the accumulation of mud and sand deposits (Fig. 4a). Very little fauna was observed growing on top of these dead coral fragments besides some small glass sponges, as well as some coral colonies of the genus *Chrisogorgia* and *Acanella*. At this point, a large deep-sea shark of the species *Hexanchus griseus* gently swam in front of the submersible. Just before reaching the rock, an underwater cable was observed laying over the ground, most likely to be the remains of an old communications cable. Interestingly, the cable was colonized by several soft corals, not yet identified to the species level (Fig. 8d). At 914 m depth a nearly vertical wall (~80º) hosted a well-defined mixed community with several species of corals and sponges. The most conspicuous coral species corresponded to the black coral *Leiopathes expansa,* with at least 15 colonies of a large (>1 m) or medium (~50-70 cm) size (Fig. 4b). In several colonies, some associated commensal galatheid crabs could be observed (Fig. 5a). Around the black coral colonies, some scleractinian corals of the species *Lophelia pertusa* were registered, mainly in the form of dead colonies with only some tips having living polyps. It is very likely that the coral deposits observed at the base of *Baixo de São Mateus* correspond to remains of this cold-water coral species, which thrived as coral reef formations in past geological times (M. Carreiro-Silva and N. Frank, unpublished data). Other abundant species observed were the yellow cup corals *Dendrophyllia cornigera* and *Leptopsammia formosa* and several hexactinellid sponges such as *Farrea occa* and small *Pheronema carpenteri* (Fig. 5b), as well as some cidarid sea urchins and brachiopods still to be identified to species level.

Moving further up the rocky wall, the density of the glass sponge *Pheronema carpenteri* increased to generate some very dense fields (Fig. 4c). Interestingly, some large colonies of the coral *Hemicorallium niobe* were observed in the transition area between the black corals and the sponges, with sizes and densities of this coral species barely recorded anywhere else in the Azores so far. The glass sponge *Pheronema carpenteri* dominated the mixed substrates until depths of 760 m, where the primnoids *Narella bellissima* and *Narella versluysi* started to appear. The abundance of these two species grew rapidly as the submarine moved further up along the slope, reaching maximum densities at 745 m depth (Fig. 4d). On top of the exposed rocks, a few lace corals of the species *Errina dabneyi* were identified, as well as the soft corals *Gersemia* sp. (Fig. 5c) and *Anthomastus agaricus,* and some small plexaurid octocorals and unidentified barnacles (Fig. 5d). At those depths, on the exposed rock, some very large sponges of the species *Haliclona magna* were also recorded. The presence of *Narella* spp. extended up to around 720 m depth, when both species disappeared, leaving *Pheronema carpenteri* to become again the dominant megabenthic species. The distribution of this glass sponge extended until 695 m depth, when suddenly disappeared to leave room for some large (> 1.5 m tall) colonies of the primnoid coral *Callogorgia verticillata* (Fig. 4e, 5e).

The dominant benthic community changed significantly from 690 m depth onwards. This final part of the dive was characterized by hard substrates home to a variety of lithistid sponge species. Up to 590 m depth, the bedrock was home to smaller sponge species, in including *Macandrewia azorica* and only a few larger specimens, mostly *Craniella longipilis* and *Leiodermatium* spp (Fig. 4f). Above 590 m depth, the number of larger sponges increased, especially those of the species cf. *Characella pachastrelloides*, with some colonies reaching 70 cm in height and 60 cm in diameter (Fig. 5f), as well as the number of encrusting species. This community lasted until the very top of the steep slope, at 490 m depth, where sand deposits became common. This very last part hosted few macrofaunal species. The fish communities observed during the whole dive were in general very impoverished, with the presence of bluntnose six-gill shark (*Hexanchus griseus*) in the deepest part, and throughout the dive some bluemouth rockfish *Helicolenus dactylopterus*, *Hoplostethus mediterraneus*, *Mora moro* and a few small Macrouridae. The dive ended at 16:05, at 496 m depth. Additional high-quality images illustrating dominant communities and species are provided as supplementary figures (Figs. S1-S2).

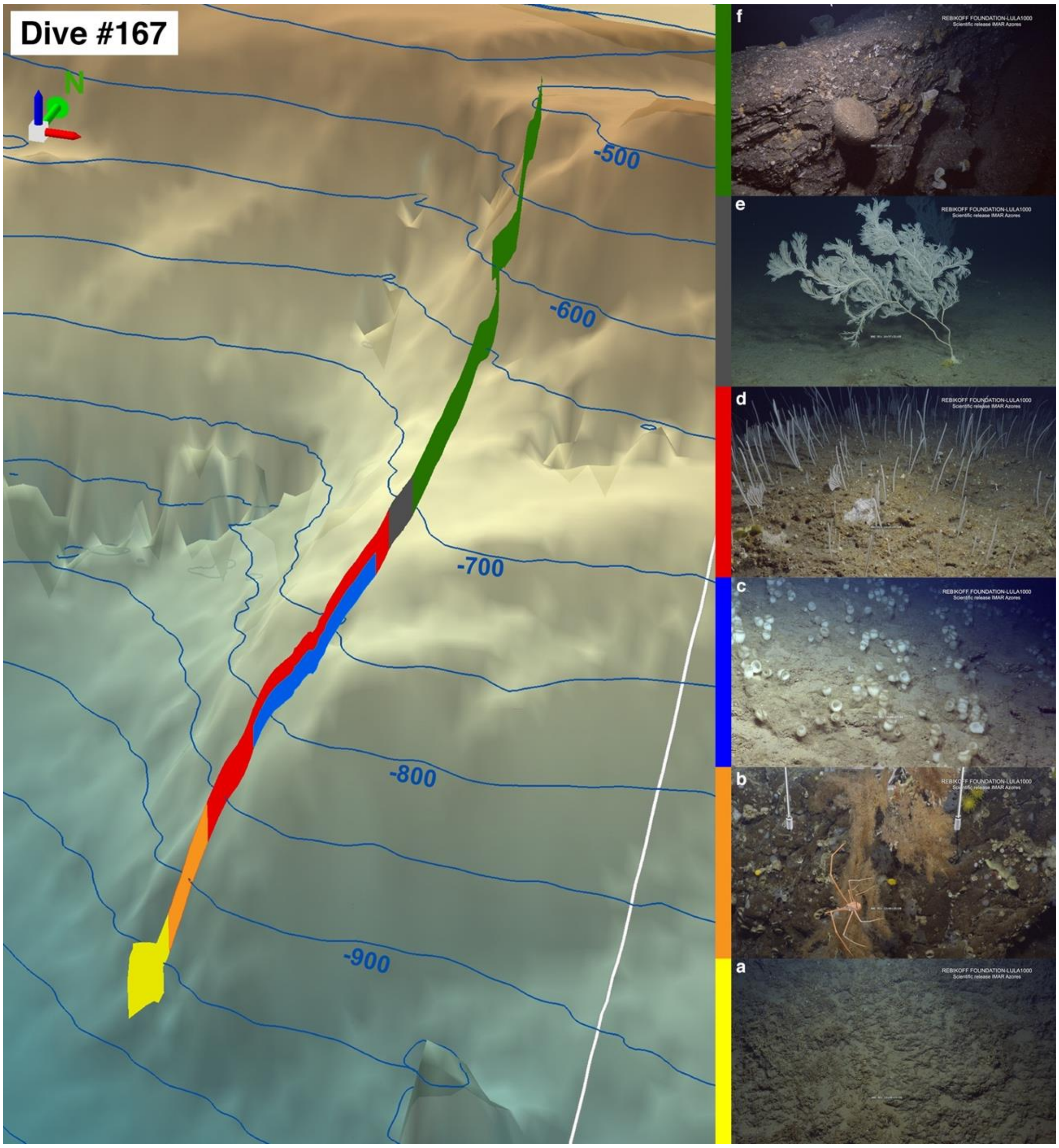

Figure 4. *Schematic representation of the depth distribution of the major benthic communities identified in Dive #1, carried out in the southern flank of* Baixo de São Mateus *with the manned submersible LULA1000. (a) Some of the coral rubble deposits found on the deepest part of the dive. (b) A vertical wall at 885 m depth with a large black coral colony of the species* Leiopathes expansa *with associated commensal galatheid crabs and some dead colonies of the scleractinian* Lophelia pertusa. *(c) Aggregation of the glass sponge* Pheronema carpenteri *at 720 m depth. (d) High densities of the primnoid corals* Narella bellissima *and* Narella versluysi *found at 745 m depth. (e) One of the large colonies of* Callogorgia verticillata *found at around 700 m depth. (f) Outcropping rock with several species of encrusting and erect sponges, including cf.* Characella pachastrelloides *and* Craniella longipilis. © *LULA 1000, Fundação Rebikoff.*

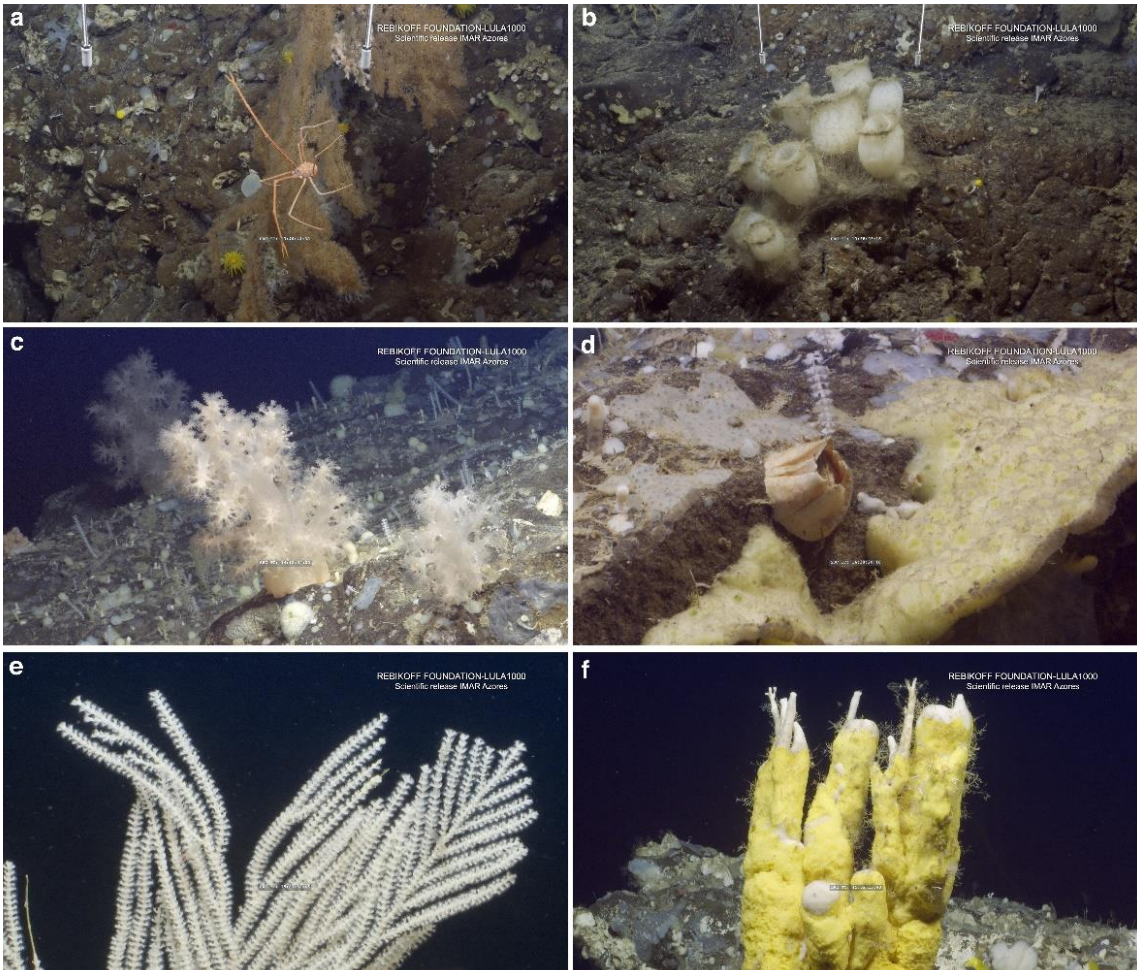

Fig. 5. *Some close-up images obtained during Dive #1 in Baixo de São Mateus. (a) Commensal galatheid crab associated with a large black coral colony of the species* Leiopathes expansa *on a vertical wall at 885 m depth. (b) The glass sponge* Pheronema carpenteri *at 720 m depth. (c) Soft coral* Gersemia *sp, at 780 m depth. (d) Unidentified barnacle at 745 m depth; (e) Close-the up of polyps of the octocoral* Callogorgia verticillata *found at 700 m depth. (f) Large specimen likely to belong to the species* Characella pachastrelloides *on the shallowest sector of the dive. © LULA 1000, Fundação Rebikoff.*

Summary of Dive #2

LULA1000 dive #168, 14th August 2019

In the second dive, the submarine reached the seafloor at 08:57, at 965 m depth, also at the base of the southern flank of Baixo de São Mateus (Fig. 3). Like in the previous dive, the manned submersible landed in a flat area characterised by soft sediments, mainly mud and fine sands. Once the submarine started to cruise above the soft bottoms, a deep-sea squid came to welcome the scientists by displaying its beauty in front of the doomed-shaped glass (Fig. 7a). Some fishes could be observed swimming just above the sediment, including a young *Mora moro*. The soft bottoms had very little macrofauna that could be identified in the images, besides some scattered colonies of the foraminifera *Syringammina fragilissima* (Fig. 6a). This organism is very common in abyssal areas of the North Atlantic, and has been regularly observed in other areas of the Azores at similar depths

Once the submarine reached rock, a large number of *Pheronema carpenteri* sponges (Fig. 6b) could be identified on its top, with some dead colonies of the scleractinian *Lophelia pertusa* and a couple of spiny scorpionfishes *Trachyscorpia cristulata*. A large colony (>1m tall) of *Leiopathes expansa* and several small solitary cup corals *Leptopsammia formosa* and the glass sponge *Farrea occa* were also recorded on the side of this first large rock. Additionally, a fishing line was observed laying just across the sponge field, although no signs of damage to any of the benthic species could be reported. Overall, up to 9 longlines could be observed during Dive #2, some of them below the common depths at which fishermen operate in the Azores region. Whilst moving through the *P. carpenteri* aggregations, some colonies of the species *Narella bellissima* and *Narella versluysi* were reported (Fig. 6c), but never reaching the densities observed in the previous dive. Additionally, some very large sponges of the species *Haliclona magna* were also recorded attached to the exposed rock (Fig. 7b).

At around 750 m depth, the number of listithid sponges increased noticeably. Some *Macandrewia azorica* and the yellow laminate sponge *Poecillastra compressa* could be identified, as well as some encrusting sponges displaying various colours. Several small colonies of the yellow sea fan *Acanthogorgia* sp. and the white coral *Hemicorallium niobe* were also observed within this community, and some white corals likely to be *Pleurocorallium johnsoni*, all of those species in very low numbers. A large homolid crab *Paromola cuvieri* was found carrying a living sponge fragment (Fig. 7d), likely *P. compressa*, which is thought to provide protection against predators (Braga-Henriques et al., 2012). When the rock showed a near vertical profile, the ancient community of the cyrtocrinid *Cyathidium foresti* and the deep-sea oyster *Neopycnodonte zibrowii* was reported (Fig. 6d, 7c). This community mainly appeared in two sections of the dive, at 715 m and 580 m depth. The second patch identified hosted the highest number of oysters, also of larger sizes. The area that existed between these two locations had a mixed relief, with sections of exposed rock followed by flat substrates covered in fine sediments. Interestingly, in one of the flat sections, a large number of Macrouridae fishes were observed gently swimming over the seabed (Fig. 7e). This aggregative behavior has not been observed in previous surveys, and will require some further investigation. The exposed rocks had a similar sponge-dominated composition, generally dominated by small-sized individuals of several species.

Opposed to the previous dive, the last part of Dive #2 extended further into the flat areas at the top of the slope, which were mostly dominated by flat sedimentary bottoms, although some large rocky outcrops were observed along the path. All those rocks were mostly covered by small Porifera, until at around 550 m depth, when this sponge-dominated community started to host very large sponges of the species *Characella pachastrelloides*, similar to what was observed in the previous dive (Fig. 6e). In this section, other common large Porifera were *Craniella longipilis* and *Petrosia crassa*, together with some sea urchins of the genus *Echinus* were observed (Fig. 7b,c). At the very end of the dive, some whip corals of the species *Viminella flagellum* started to appear (Fig. 6f), always in very low densities and observed as scattered colonies. Spider crabs of the genus *Anamathia* were observed on the upper branch axis of those colonies (Fig. 7g). Also several large (>1m tall) primnoids of the species *Callogorgia verticillata* were identified, some of which seemed to have broken branches, most likely due to the effects of longline fishing. Some colonies of *Callogorgia verticillata* were parasitized by the zoantharia *Zibrowius primnoidus* (Fig. 7h). Not many fish species were spotted on the flat areas at the end of the dive besides several bluemouth rockfish *Helicolenus dactylopterus* and the silver roughy *Hoplostethus mediterraneus*. The dive ended at 14:17, at 493 m depth. Additional high-quality images illustrating dominant communities and species are provided as supplementary figures (Figs. S3-S4).

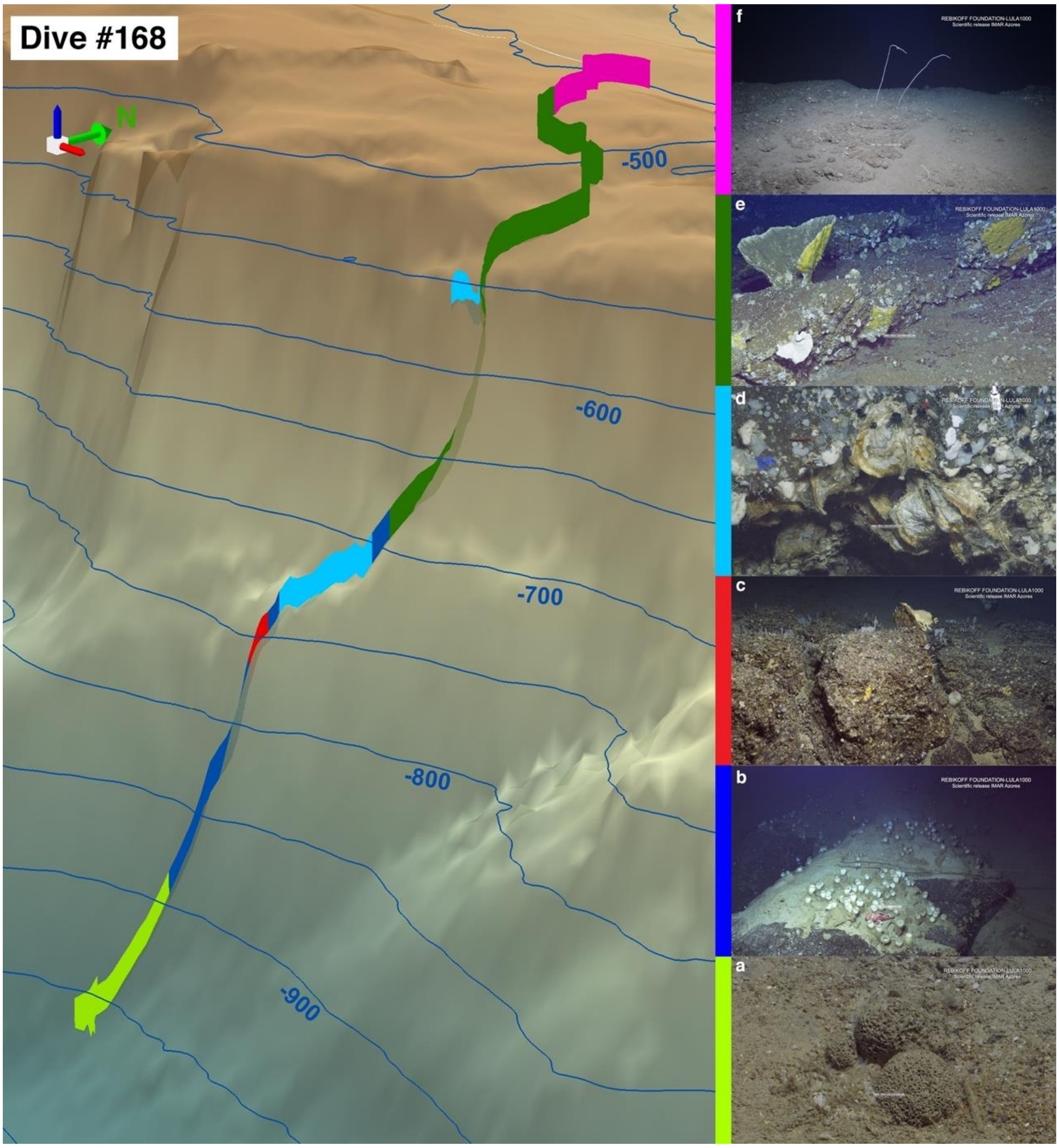

Figure 6. *Depth distribution of the major benthic communities identified in Dive #2, carried out in the southern flank of Baixo de São Mateus with the manned submersible LULA1000. (a) Two individuals of the Foraminifera* Syringammina fragilissima *observed in the deepest area investigated. (b) Rocky outcrop at the base of the slope covered with sponges of the species* Pheronema carpenteri*, with a fishing line laying on top of it. (c) Some small colonies of the primnoid coral* Narella versluysi *on a rocky outcrop at 755 m depth. (d) Aspect of the oysters and crinoids that make up the ancient community of* Neopycnodonte zibrowii *and* Cyanthidium foresti. *(e) One of the few rocky outcrops colonized by several species of sponges, inlcuding large* Characella pachastrelloides*, found below 500 m depth. (f) Some of the few colonies of the whip coral* Viminella flagellum *observed in the mixed substrates at the very end of the dive. © LULA 1000, Fundação Rebikoff.*

Figure 7. *Some close-up images obtained during Dive #2 in Baixo de São Mateus. (a) A curious squid that came to examine the submarine at the beginning of the dive at 950 m depth. (b) A very large specimen of the sponge* Haliclona magna *on the hard substrates at 865 m depth. (c) Aspect of the oysters and crinoids that make up the ancient community of* Neopycnodonte zibrowii *and* Cyanthidium foresti*. (d) Homolid crab* Paromola cuvieri *carrying a sponge fragment. (e) Fish of the* Macrouridae *family. (f) Sea urchin likely from the genus* Echinus *grazing on a large* Craniella longipilis *sponge. (g) Octocoral* Viminella flagellum *hosting two deep-sea spider crabs* Anamathia *sp. (h) Octocoral* Callogorgia verticillata *parazitised by the yellow zoantharia* Zibrowius primnoidus. *© LULA 1000, Fundação Rebikoff.*

Overview of the benthic communities of Baixo de São Mateus

Based on this preliminary analysis of the video images, a total of seven benthic communities can be listed for the seamount ridge *Baixo de São Mateus* (Table 2, Fig. 4 and 6), displaying a very clear zonation along the depth gradient. The deepest areas explored correspond to flat soft bottoms with the Foraminifera *Syringammina fragilissima*. The diversity of benthic species increases exponentially when the rock outcrops, especially in vertical or very slopping sectors. At the base of the slope, large colonies of the black coral *Leiopathes expansa* can be identified, surrounded by scleractinian corals of the species *Lophelia pertusa* and *Leptopsammia formosa,* as well as the glass sponge *Farrea occa*. Mixed bottoms with a lower slope around these rocky outcrops are colonized by the glass sponge *Pheronema carpenteri*. Further up along the slope, the association between the primnoids *Narella bellissima* and *Narella verluysi* is common, with dense coral gardens at 750 m depth. Below 700 m depth, the rock become more frequent and experiences a clear change towards a sponge-dominated community, with giant sponges of the species cf. *Characella pachastrelloides,* among many others. At those depths, some vertical walls are colonized by the oyster *Neopycnodonte zibrowii* and the crinoid *Cyathidium foresti,* described as a 'living fossil community' with its origin dated to 60 million years ago (Wisshak et al., 2009).

Table 2. Summary of the benthic communities identified at *Baixo de São Mateus* during the exploratory dives performed with LULA1000 submersible.

Benthic communities		**Depth range (m)**
Coral-dominated communities	Coral gardens with *Narella bellissima* and *Narella versluysi* on outcropping rocks	700-800
	Vertical walls with *Leiopathes expansa, Lophelia pertusa, Leptopsammia formosa* & *Farrea occa*	1000
Sponge-dominated communities	Aggregations of *Pheronema carpenteri* on soft sediments	700-900
	Multispecific aggregations of lithistid porifera, including cf. *Characella pachastrelloides*, *Petrosia crassa*, *Craniella longipilis* and *Macandrewia azorica* on outcropping rocks	500-700
	Aggregations of encrusting and other large lithistid Porifera on basaltic rock	500-600
Other communities	Fields of cf. *Syringammina fragilissima*	970
	Living fossil communities of *Neopycnodonte zibrowii* & cf. *Cyathidium foresti* on vertical walls	600-700

4. Human disturbance on the benthic communities of *Baixo de São Mateus*

Remnants of longline fishing (e.g. ropes and monofilament lines) were observed during the two dives conducted at *Baixo de São Mateus*, particularly between depths of 500-700 m, broadly coinciding with depths generally exploited by longline fishing activities (Fig. 8a,b), although a few lines were recorded at depths of 860-885 m. Along Dive #1, a total of 4 lines were observed, mostly entangled around large rocky outcrops and without evidence of damage to the benthic fauna. Lost fishing gears were more common in Dive #2, with a total of 9 lines and cables observed during the dive, in many cases suspended in the water column.

Several broken or damaged colonies of corals and sponges were observed in Dive #2 (Fig. 8e,f), potentially indicating mechanical damage by fishing, although the absence of fishing gears next to the broken colonies makes it difficult to eliminate natural causes, such as predation. Nevertheless, observations of *Callogorgia verticillata* showing high colonization by the zoanthid *Zibrowius primnoidus* could be an indirect consequence of fishing damage, where the zoantharia takes advantage of abraded tissue free portions of the colony skeleton for colonization (Carreiro-Silva et al., 2011, 2017). Interestingly during Dive #1, a communications submarine cable colonized by soft corals and gorgonians was observed laying over the seafloor (Fig. 8c,d). Submarine cables cross the Azores region, but they cover a reduced area and therefore do not represent an important human impact to marine ecosystems (see Appendix 1 Section 5.5 of the Blue Paper). In fact, submarine cables have been used as a unique opportunity to assess the potential for spontaneous natural regeneration of deep-sea fauna recruiting on hard artificial substrates on the H2020 project MERCES. By knowing the date of deployment of the submarine cable, measurements of the size of the organisms can provide an indication of the likely growth rates of these organisms, which have been rarely quantified. The presence of marine litter was minimal, with only a lost ceramic cup found during both dives.

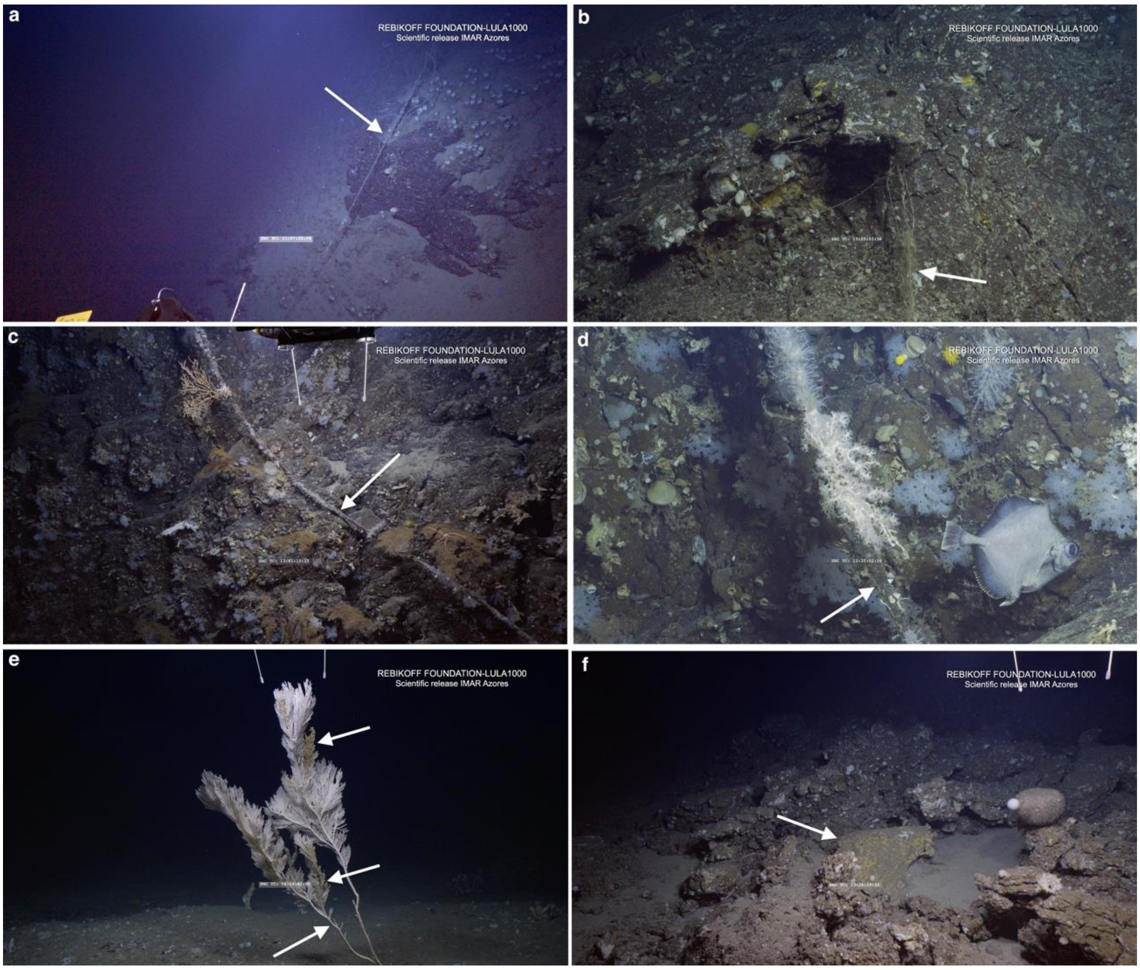

Figure 8. *Examples of human disturbance on benthic communities at Baixo de São Mateus. (a) Lost fishing cable across a* Pheronema capenteri *field observed at 845-885 m depth during Dive #2. (b) Lost monofilament fishing line entangled on rocky outcrops at 630 m depth in Dive #1. (c-d) Submarine communications cable colonized by octocorals and other epibenthic fauna observed at 885 m depth during Dive #1. (e) Large* Callogorgia verticillata *coral with signs of broken branches (bottom arrow) and several colonies of zoanthids growing on some of its remaining branches (upper two arrows). (f) A large specimen of the sponge species cf.* Characella pachastrelloides *laying over the seabed in a very uncommon position, likely to be produced by the dislodgement of the specimen by a fishing line during its retrieval. © LULA 1000, Fundação Rebikoff.*

5. Assessment of Baixo de São Mateus against the VME criteria

The seamount ridge *Baixo de São Mateus* was assessed against each of the five Food and Agricultural Organization (FAO) criteria for defining what constitute a Vulnerable Marine Ecosystem (VME) using expert judgement (UNGA, 2006; FAO, 2009; 2016). The criteria are:

- **Criteria 1:** ***Uniqueness or rarity.*** An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include: habitats that contain endemic species habitats of rare, threatened or endangered species that occur only in discrete areas nurseries or discrete feeding, breeding, or spawning areas.
- **Criteria 2:** ***Functional significance of the habitat.*** Discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.
- **Criteria 3:** ***Fragility.*** An ecosystem that is highly susceptible to degradation by anthropogenic activities.
- **Criteria 4:** ***Life-history traits of component species that make recovery difficult.*** *E*cosystems that are characterised by populations or assemblages of species with one or more of the following characteristics: slow growth rates, late age of maturity, low or unpredictable recruitment, and/or long-lived.
- **Criteria 5:** ***Structural complexity.*** An ecosystem that is characterised by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.

In general, *Baixo de São Mateus* appeared to host low diversity of benthic communities and species when compared to other underwater features surveyed in the Azores region (see Deliverable 3). Although the "living fossil community" composed of the oyster *Neopycnodonte zibrowii* and the crinoid *Cyathidium foresti* (Wisshak et al., 2009) recorded on the vertical walls of *Baixo de São Mateus* is considered unique to the Azores region, this community has also been recorded in several other island slopes of the region, and thus cannot be considered as a rare occurrence at the scale of the Azores (Criteria 1, Table 3). Likewise, the CITES protected *Leiopathes expansa* that was recorded on the deepest part of the vertical walls is currently protected elsewhere in the Azores, as for example in the Formigas bank.

There was limited information to assess the life history traits of the different species that make up the benthic communities of *Baixo de São Mateus* (FAO Criteria 2, Table 3) due to major knowledge gaps on species reproductive cycles, growth rates, reproductive output, larval biology and dispersal, and recruitment rates. There exist some exceptions, such as the life span of several millennia and extremely low growth rates (<1 mm) of the black corals of the genus *Leiopathes* in the Azores (Carreiro-Silva et al., 2013), although this species occurred in low numbers in *Baixo de São Mateus*. Preliminary information on the longevity and reproduction of the large arborescent octocoral *Callogorgia verticillata* indicates age spans of around 500 years and low reproductive output (Carreiro-Silva unpublished data), but this species was also present in very low numbers.

The fragility (FAO Criteria 3, Table 3) of the communities that exist in *Baixo de São Mateus* was assessed through the evidence of vulnerability to physical contact, such as accidental capture during longline fishing (based on Sampaio et al., 2012), and the capacity of species for retraction, retention or re-growth or natural protection in some way (e.g. vertical walls or overhangs not accessible to fishing or located below maximum longline fishing depths). Although some species, i.e. large *C. verticillata* and cf. *Characella pachastrelloides* presented some signs of fishing impact, most other species showed intact colonies. This was the case of *Narella* species that formed the best-structured and denser coral garden identified in *Baixo de São Mateus*. The simple morphological structure and small size of *Narella* species and their occurrence close to the depth limit of longline fishing naturally protects them from such human activity. Moreover, the occurrence of unique species of black corals and ancient oysters on vertical walls that have a difficult access to fishing naturally protects them from fishing-related impacts.

As for functional significance (FAO Criteria 4, Table 3) there is limited information on the role of the identified coral and sponge communities as nursery areas for other species, nutrient regeneration, and carbon remineralization and sequestration. Nevertheless, the number of species and communities, a proxy for functional significance (Snelgrove et al. 2014; Zepelli et al., 2016), was relatively low compared to other underwater features already explored in the Azores region. The communities identified in *Baixo de São Mateus* generally had low structural complexity (FAO Criteria 5, Table 3) with species of simple morphologies and small sizes, generally present in low densities, and consequently likely limited number of niches for associated species, low ecological interactions, and simple food web complexity.

Table 3. Assessment of the seamount ridge *Baixo de São Mateus* against the five criteria for defining what constitutes a Vulnerable Marine Ecosystem (FAO, 2009).

FAO criteria	Assessment
Uniqueness or rarity	No special rare or unique occurrences. Presence of "living fossil community" composed of long-lived oysters and crinoids (*Neopycnodonte zibrowii* and *Cyathidium foresti*) only reported for the Azores region so far. Some living colonies of the cold-water coral *Lophelia pertusa*, not a common sighting. Black coral *Leiopathes expansa* listed as a VME indicator species and CITES protected.
Functional significance	Overall, low diversity of coral- and sponge-dominated communities.
Fragility	Presence of numerous fishing lines along the dives, but low number of visibly damaged coral and sponge species.
Life-history traits	Most long-lived species not unique and in very low numbers. Black coral *L. expansa* with life spans of several millennia and low growth rates. Large colonies of the octocoral *Callogorgia verticillata* likely several centuries old.
Structural complexity	Overall, low density and small size of habitat forming corals and sponges, although locally there are some very dense patches of primnoid corals *Narella* spp. and some large aggregations of the glass sponge *Pheronema carpenteri*.

6. Management implications

Based on the assessment described above, the seamount ridge ***Baixo de São Mateus*** **does not fit the FAO criteria to be considered a VME** and thus there is no sufficient scientific information to recommend this area as high priority for conservation in the Azores. Despite the presence of long-lived species, such as the millennia-old black coral *Leiopathes* and ancient fauna (*Neopycnodonte zibrowii* and *Cyathidium foresti*), there was an overall low number of species and communities, also present in low densities, when compared to other geomorphological features in the Azores. In addition, none of the communities identified are unique at the scale of the Azores and are already present in other features recommended as priority areas for conservation. Although Baixo São Mateus is an important fishing ground in the Azores, the low natural diversity of the benthic communities observed may suggest that existing fishing pressures in Baixo São Mateus will likely not produced significant adverse impacts in the existing benthic living communities.

However, it should be noticed that the present assessment is based on only two video transects that covered a limited area of Baixo São Mateus. It is possible that we may have missed some important communities or areas with higher species diversity. In addition, there was limited information to assess the life history and functional significance of component species and communities due to major knowledge gaps on the reproductive cycles, growth rates, reproductive output, larval biology and dispersal, recruitment and their role in the functioning of the ecosystems such as nursery areas for other species, nutrient regeneration, and carbon remineralisation and sequestration. Therefore, continued scientific research is necessary to better understand the distribution, structural and functional role of deep-sea benthic communities and inform adaptive management and conservation policies.

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Supplementary figures S1-S4

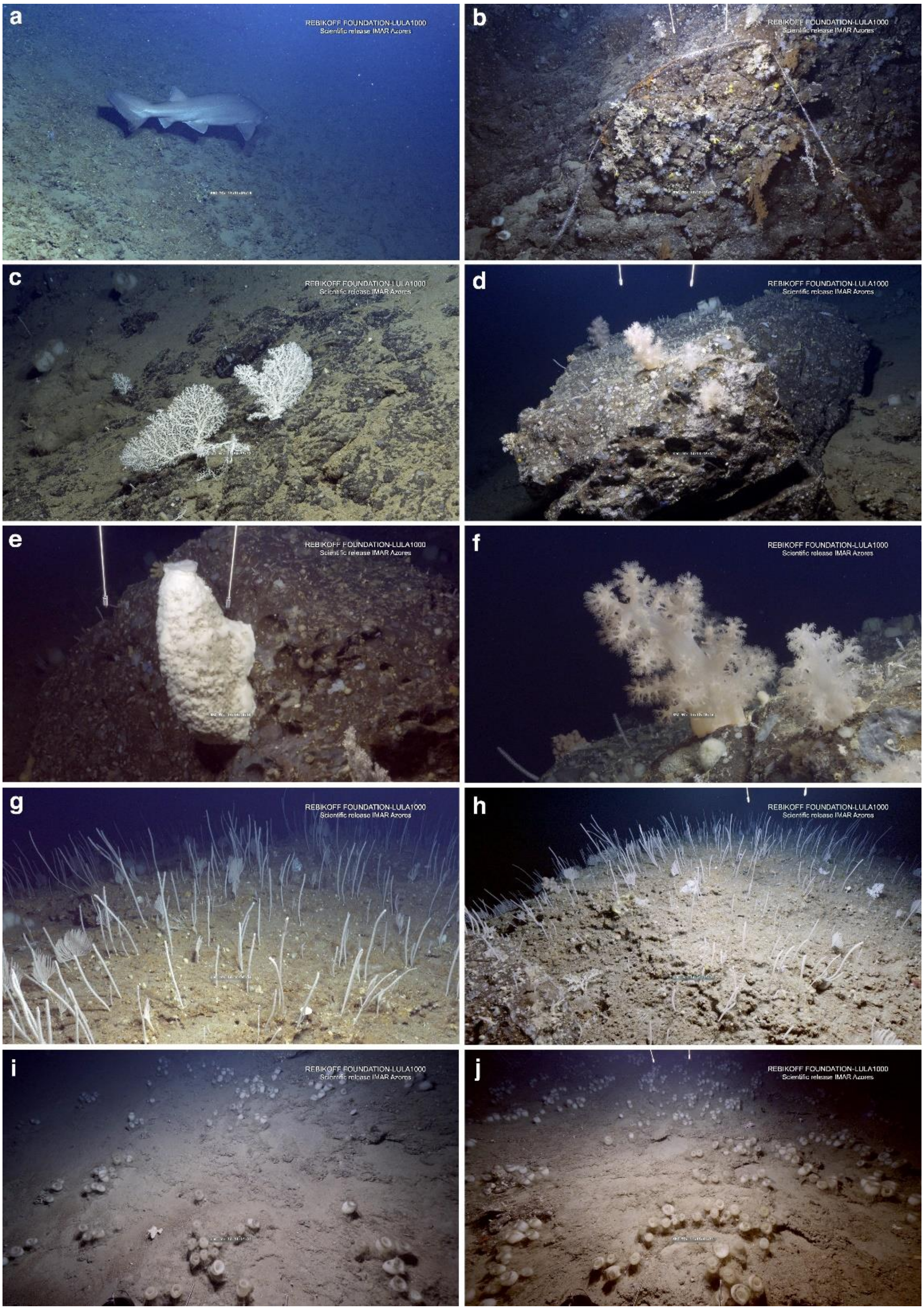

Figure S1. *Images of dominant communities and species observed on Dive #1. (a) Bluntnose six-gill shark* Hexanchus griseus *at 920 m depth. (b) Lost fishing cable entangled on rocky outcrops colonized by black corals* Leiopathes expansa*, scleractinian corals and encrusting sponges at 880 m depth. (c) Octocoral* Hemicorallium niobe *on hard substrate at 829 m depth. (d) Rocky outcrop colonized by the soft coral* Gersemia *sp., whip coral* Narella versluysi *and a few sponges* Pheronema carpenteri *at 783 m depth. (e) Desmosponge* Haliclona magna *on rock substrate at 770 m depth. (f) Close up of soft coral* Gersemia *sp at 776 m depth. (g-h) Dense coral gardens formed by the octocorals* Narella bellissima *and* Narella versluysi *at 770 m depth. (i-j) Aggregation of the glass sponge Pheronema carpenteri observed at depths between 720 to 790 m. © LULA 1000, Fundação Rebikoff.*

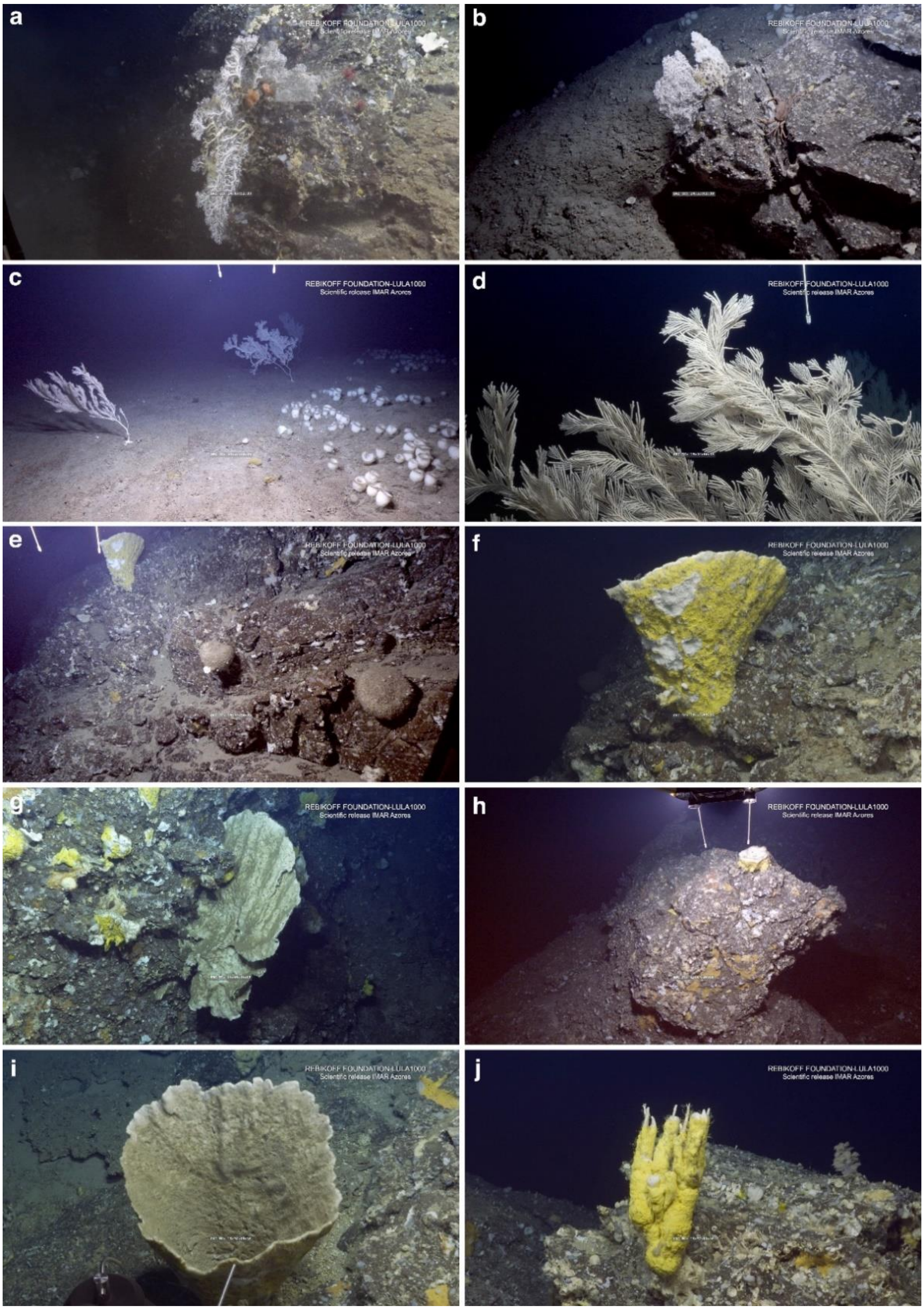

Figure S2. *Iimages of dominant communities and species observed during Dive #1. (a) Rock outcrop colonized by the stylasterid* Errina dabneyi, *solitary scleractinian* Desmophyllum dianthus *and soft coral* Anthomastus agaricus *at 712 m depth. (b) The stylasterid* E. dabneyi *with the crab* Chaceon affinis *on rocky outcrops at 700 m depth. (c) Aggregations of the glass sponge* Pheronema carpenteri *next to large colonies of the octocoral* Callogorgia verticillata *at 695 m depth. (d) Close-up of the upper branches of a large* C. verticillata. *(e) Outcropping rock with several species of encrusting and erect sponges, including cf.* Characella pachastrelloides *and* Craniella longipilis *at 568 m depth. (f) Close-up of large desmosponge* C. pachastrelloides. *(g-h) Rocky outcrops colonized by several species of sponges, including large* Leiodermatium *sp, and* C. pachastrelloides *at 530 m depth. (i) Top view of the giant desmosponge* C. pachastrelloides. *(j) Large specimen likely representing a morphotype of the species* C. pachastrelloides *on the shallowest sector of the dive, at 500 m depth. © LULA 1000, Fundação Rebikoff.*

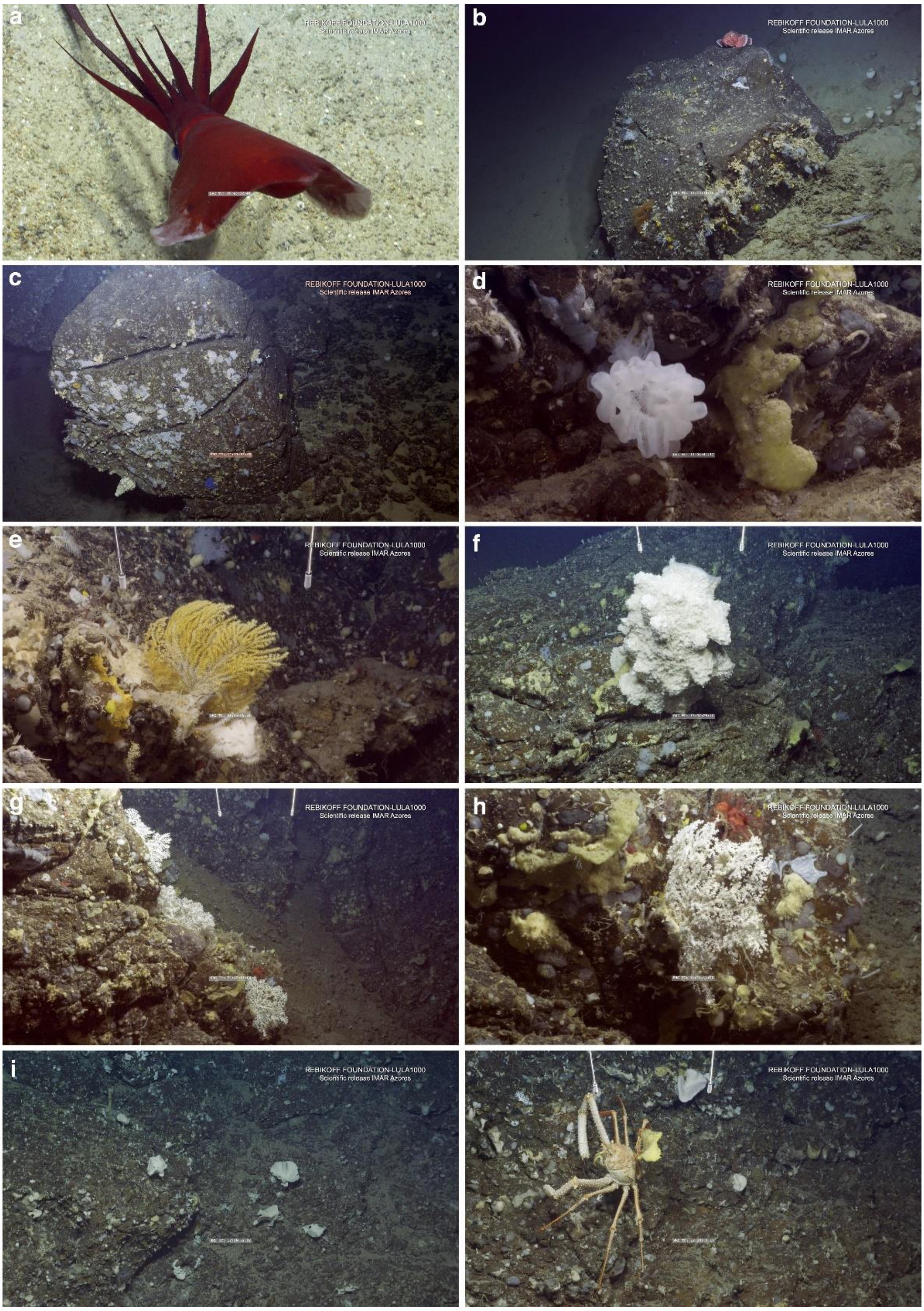

Figure S3. *Images of dominant species and communities observed during Dive #2. (a) A curious squid that came to examine the submarine at the beginning of the dive. (b) Large spiny scorpionfishes* Trachyscorpia cristulata *on top of a rocky outcrop at 870 m depth. (c) Rock colonized by encrusting sponges at 870 m depth. (d) Glass sponge* Farrea occa *on hard substrate at 730 m depth. (e) Yellow sea fan* Acanthogorgia *sp. at 730 m depth. (f) Large specimen of the desmosponge* Haliclona magna *at 720 m depth. (g) Rocky outcrop with several colonies of the octocoral* Hemicorallium niobe *and encrusting sponges at 720 m depth. (h) Close-up of* H. Niobe. *(i) Hard substrate colonized by the desmosponge* Macandrewia azorica *at 630 m depth. (j) Large homolid crab* Paromola cuvieri *carrying a living sponge fragment at 610 m depth. © LULA 1000, Fundação Rebikoff.*

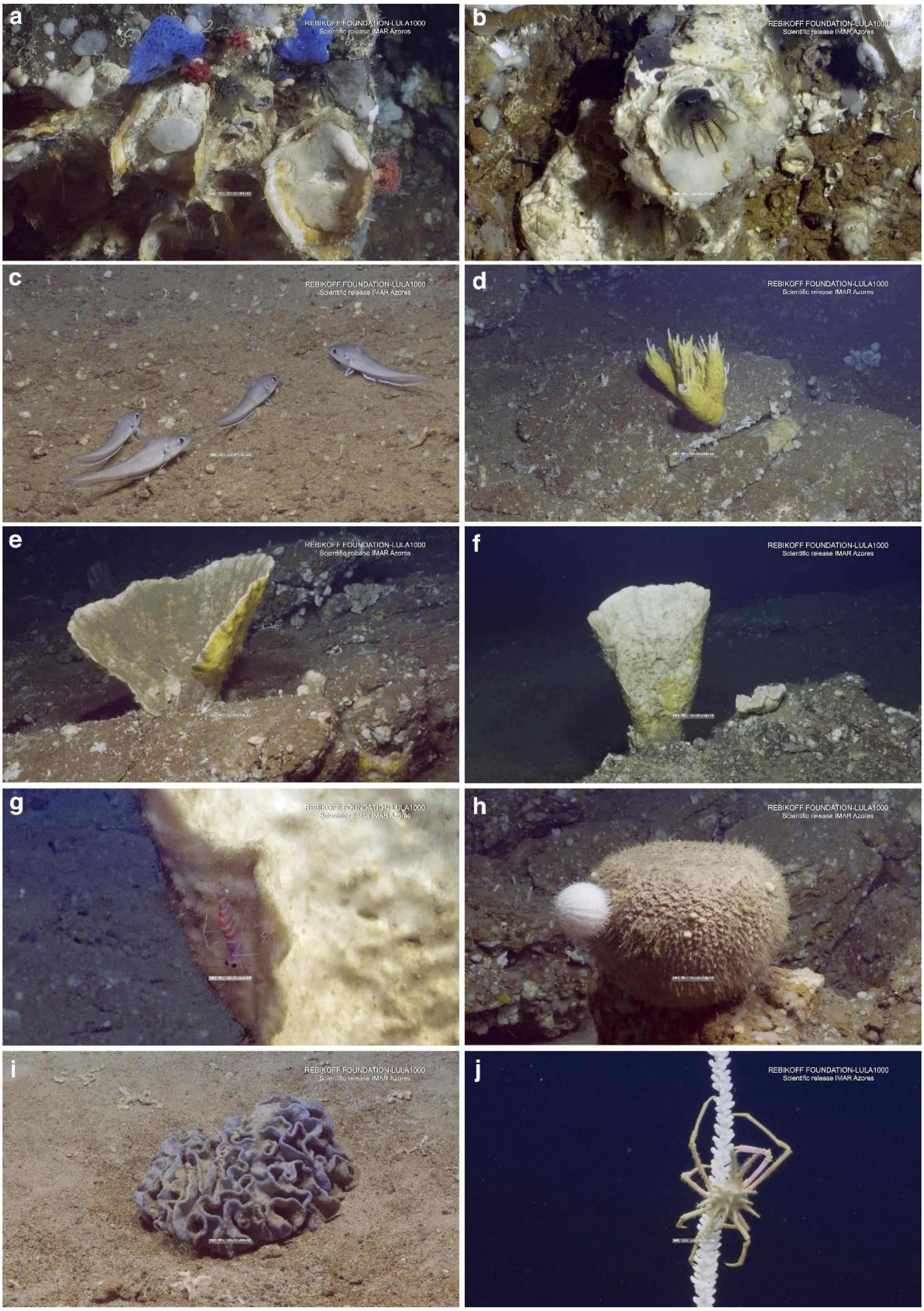

Figure S4. *Images of dominant species and communities observed during Dive #2. (a) Aspect of the oysters and crinoids that make up the ancient community of* Neopycnodonte zibrowii *and* Cyanthidium foresti *on a vertical wall at 580 m depth. (b) Close-up of an oyster and a crinoid. (c) Macrouridae fishes swimming over the seabed at 550 m depth. (d) Large specimen likely representing a morphotype of the species* Characella pachastrelloides *at 550 m depth. (d-e) Typical appearance of* Characella pachastrelloides. *(f) Shrimp on a desmosponge. (h) Sea urchin grazing on a large* Craniella longipilis *sponge. (i) Desmosponge* Leiodermatium *sp. on soft substrate at 480 m depth. (j) Spider crab of the genus* Anamathia *on the whip coral* Viminella flagellum *at 490 m depth. © LULA 1000, Fundação Rebikoff.*