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**Evaluating seabed habitat representativeness across a diverse
marine protected area network on the Mid-Atlantic ridge**



UNIVERSIDADE DO ALGARVE

Faculdade de Ciências e Tecnologia

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Mestrado em Biologia Marinha

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Declaração de autoria de trabalho

EVALUATING SEABED HABITAT REPRESENTATIVENESS ACROSS A DIVERSE
MARINE PROTECTED AREA NETWORK ON THE MID-ATLANTIC RIDGE

Declaro ser o autor deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.



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Abstract

Marine ecosystem-based management requires good spatial information on the distribution of marine species and habitats. Because such information is often limited to a few sampled locations, modelling techniques can be applied to produce predictive distribution maps. Harmonized broad-scale seabed habitat map was recently produced for Europe under the EMODnet Seabed Habitats programme. This new information was used to produce an extent-based evaluation of the representativeness and level of protection conferred by the current MPA network in the Azores (mid-north Atlantic ridge) to the variety of benthic marine habitats found in this region. A more objective assessment of the protection provided to these habitats was obtained by applying a scoring system to the MPAs based on the number of allowed extractive and non-extractive human activities, and on their potential impact on marine biodiversity and habitats. Results show that habitats protected by the network are nearly entirely classified as highly protected. In total, 26 habitats (including seven endangered and two rare) meet the Aichi Biodiversity Target 11 of 10% of coastal and marine areas protected by 2020. However, another 29 habitats fail to meet even the lowest target (four on-shelf habitats and 25 deep-sea habitats). These results highlight the need to extend effective protection levels to bathyal and abyssal habitats and to apply adequate ecological coherence criteria in the region. This approach sets a standard than can be used wherever similar information is available, be it in other European regions or beyond.

Keywords: protected area network, representativeness, marine habitats, EUNIS, regulation-based classification, Azores

Resumo

A gestão baseada nos ecossistemas marinhos é considerada como a abordagem mais abrangente e desejável para gerir as atividades humanas nos mares e oceanos, desde há pelo menos três décadas. Atualmente, esta estratégia é central em várias iniciativas de planeamento espacial marinho, diretivas europeias (Natura 2000, OSPAR, Diretiva Quadro Estratégia Marinha) e projetos de crescimento azul (Blue Growth). Um componente crítico subjacente aos seus processos de tomada de decisão é um bom conhecimento sobre a diversidade, extensão e distribuição dos habitats e das espécies marinhas. Frequentemente, esse tipo de informação é limitada a certos locais amostrados, podendo diferentes técnicas de modelação ser aplicadas para produzir mapas preditivos de distribuição. Em conformidade com essa necessidade, a catalogação e o mapeamento harmonizado de habitats bentónicos em escalas regionais tornaram-se uma prioridade nas últimas duas décadas, fortalecendo os esforços de conservação marinha e auxiliando na elaboração de relatórios obrigatórios.

Neste contexto, foi recentemente produzido um mapa harmonizado dos habitats do fundo marinho em larga escala para a Europa, no âmbito do programa EMODnet Seabed Habitats, cobrindo desde o Mar de Barents à Macaronésia, e mares adjacentes como o Mediterrâneo e o Mar Negro. Este mapa segmenta os ambientes do fundo do mar de acordo com a classificação de habitat do Sistema Europeu de Informação da Natureza (EUNIS) - um sistema abrangente de classificação que utiliza uma série de critérios ambientais para criar e delimitar espacialmente classes de habitat de forma hierárquica e harmonizada. Este tipo de mapas harmonizados facilitam o estudo e gestão de habitats do fundo do mar entre regiões e países. Uma aplicação óbvia e fundamental é a consideração dos mesmos no desenho de uma rede representativa de áreas marinhas protegidas (AMPs), sendo esta uma componente fundamental nas políticas de gestão e conservação de recursos naturais e uma necessidade à escala das bacias oceânicas. Idealmente, uma rede de AMPs bem projetada deve representar a amplitude de habitats vulneráveis presentes em uma determinada região, bem como as ligações funcionais entre eles (ou seja, a conectividade). Tais considerações nem sempre são realizadas, nomeadamente em casos onde a rede de AMPs foi montada ao longo de décadas, por meio de uma sucessão de iniciativas descoordenadas, como é o caso do arquipélago dos Açores.

Esta região de Portugal, é um setor remoto do Atlântico Nordeste, associado a uma importante Zona Económica Exclusiva (ZEE), totalizando quase em 1 milhão de quilómetros quadrados e englobando um mosaico variado de habitats sublitorais e profundos, situados na cordilheira do

meio do Atlântico. Múltiplos usos humanos têm impactado os ecossistemas marinhos, principalmente por meio da exploração intensiva de algumas espécies marinhas comerciais, degradação de habitats e poluição localizada. Os seus ambientes costeiros são considerados como significativamente impactados.

Neste trabalho, utilizaram-se as novas informações para produzir uma avaliação da rede de AMPs dos Açores, baseada tanto na extensão da sua representatividade, como do nível de proteção conferido à variedade de habitats marinhos bentónicos encontrados na região. Uma avaliação mais objetiva da proteção oferecida aos habitats é obtida mediante a aplicação de um sistema de pontuação às AMPs, com base no número de atividades humanas extrativas e não extrativas permitidas e seu potencial impacto na biodiversidade e habitats marinhos. De acordo com este sistema de classificação, as AMPs / zonas foram classificadas e pontuadas considerando 1) o número de artes de pesca permitidas (comerciais e / ou recreativas); 2) o impacto das artes de pesca (comerciais e / ou recreativas); 3) a presença de aquicultura e exploração do fundo do mar; e 4) permissão de atividades recreativas não-extrativas (ou seja, ancoragem e passeios de barco). A metodologia permitiu categorizar a força de regulamentação em vigor, com fim a proteger os habitats bentónicos.

Os resultados mostram que a ZEE é amplamente dominada pelo habitat do mar profundo (25% batial e 74% abissal), enquanto os habitats rasos (incluem a plataforma das ilhas e os cumes das montanhas submarinas) representam menos de 1%. Um total de 28 tipos únicos de habitats EUNIS foram identificados na ZEE dos Açores. Esse número aumenta para 55 se considerarmos o mesmo habitat por zona biológica, substrato e exposição hidrodinâmica (quando aplicável). Nove dos habitats EUNIS identificados estão listados na Lista Vermelha da UE de habitats marinhos, quatro como ameaçados de extinção e os restantes habitats como vulneráveis. Os habitats protegidos pela rede são quase inteiramente classificados como altamente protegidos. No total, 26 habitats (sete dos quais estão ameaçados e dois são raros) atendem à meta de biodiversidade de Aichi 11, que visa possuir 10% das áreas costeiras e marinhas protegidas até 2020. Outros 29 não atingem a meta mais baixa (quatro habitats da plataforma da ilha e 25 habitats do mar profundo), destacando a necessidade de ampliar a proteção dos habitats batiais e abissais e aplicar critérios adequados de coerência ecológica.

A aplicação de uma classificação de AMP baseada em regulamentação fornece um “state-of-the-art” e uma maneira objetiva de qualificar números com base na extensão, que por si só, poderiam influenciar a percepção de quão bem o ecossistema está protegido. Mostra-se que quase toda a rede de AMPs é classificada como altamente protegida, destacando uma escassez

geral de áreas totalmente protegidas em toda a ZEE da região. Tais áreas poderiam contribuir para uma proteção mais efetiva da biodiversidade marinha dos Açores contra pressões diretas e difusas. Na atual configuração da rede de AMPs, níveis mais altos de proteção, como os sugeridos na “Promessa de Sydney” (30% das áreas totalmente protegidas), poderiam apenas ser previstos para habitats infralitorais, e somente se as AMPs da plataforma da ilha fossem vigorosamente regulamentadas. Os resultados demonstram ainda que poucas AMPs existentes incluem algum tipo de zoneamento, ao contrário das recomendações de planeamento marinho para estabelecer zonas-tampão em torno dos locais principais para a conservação. O presente estudo fornece assim uma base para os decisores abordarem as deficiências de conservação por habitats marinhos e demonstram uma abordagem transponível para outras regiões europeias ou fora delas, sempre que informações semelhantes estiverem disponíveis. Os novos mapas de habitats e AMPs devem facilitar o desenho de uma rede que atenda às metas internacionais de conservação baseadas em extensão, bem como aos critérios de coerência ecológica. Melhorar a confiança em algumas classes de habitat exige pesquisas mais refinadas que devem permitir a discriminação de habitats prioritários cuja ocorrência e distribuição na região é atualmente impossível de avaliar.

Palavras-chave: rede de áreas marinhas protegidas, representatividade, habitats marinhos, EUNIS, classificação da proteção, Açores

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List of Abbreviations

AMP – Azorean Marine Park

AP – archaeological park

EEZ – Exclusive Economic Zone

EMODnet – European Marine Observation Data Network

EUNIS – European Nature Information System

FMA – fisheries management area

HR – harvest reserves

INP – Island Natural Park

IUCN – International Union for Conservation of Nature

KE – kinetic energy

MPA – marine protected area

OSPAR – Convention for the Protection of Marine Environment of the North-East Atlantic

Chapter 1: Introduction

Ecosystem-based management is now accepted as the best approach to manage human activities in the marine environment (McLeold & Leslie 2012). Among other factors, it largely requires a good knowledge on the composition, diversity and extension of seabed habitats which are fundamental for scenarios underlying decision-making processes. Consequently, there has been an increasing demand for marine spatial planning programmes, European Directives reporting requirements, marine conservation efforts and Blue Growth projects that boosted the cataloguing and mapping of benthic habitats over the last two decades (Harris & Baker 2011; Vasquez et al. 2015; Populus et al. 2017). Two very important tools in this framework are a classification (and mapping) of the habitats, and a classification (and mapping) for the levels of protection via Marine Protected Areas of different forms.

1.1 EUNIS Habitat classification and habitat mapping

In Europe, broad-scale advances have been made chiefly under the projects EUSeaMap, BALANCE, MESH and MESH-Atlantic (Al-Hamdani & Reker 2007; Coltman et al. 2008; Vasquez et al. 2015; Populus et al. 2017), which compiled available seabed habitat maps for all European Seas and developed a method to model the broad-scale habitat distribution. The products of these projects have been brought together in a seamless broad-scale seabed habitat map that is publicly available via the EMODnet Seabed Habitats portal (<https://www.emodnet-seabedhabitats.eu/access-data/download-data/>). Identified habitat types were classified according to the European Union Nature Information System (EUNIS) habitat classification, a comprehensive classification system which provides a harmonised, hierarchical nomenclature based on defined criteria for habitat identification via environmental variables (Davies et al. 2004). The current version of the classification starts at level 1, where marine habitats are distinguished from their terrestrial counterparts. Level 2 broad habitat types are defined using a set of variables linked to substrate, depth and light. At level 3 (habitat complexes) hydrodynamic exposure (kinetic energy, KE) is used to segment rocky areas while sediments are divided based on their grain size, depth or exposure. The discrimination of level 4 habitats (biotope complexes) and beyond (level 5 biotopes and level 6 sub-biotopes) further requires the integration of increasingly refined biological information (Connor et al. 2004) (Figure 1.1).

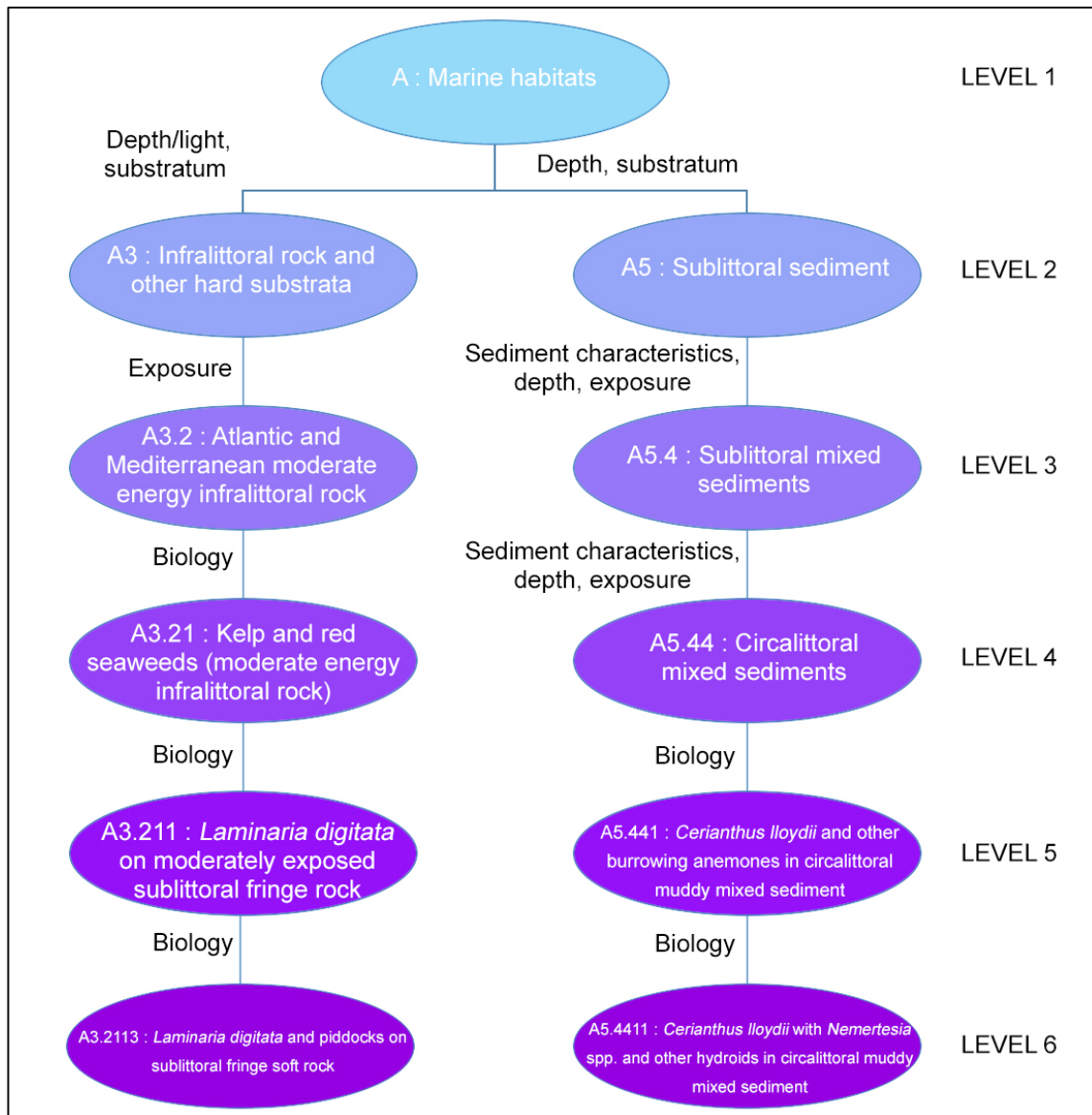


Figure 1.1. Examples of the EUNIS habitat classification with its hierarchy and the main criteria used for its level classification. An example of a rocky habitat is represented on the left and of a sandy habitat on the right side.

The resulting broad-scale map covers all European basins and seas, from the Black Sea to the Mediterranean, Macaronesia and the Barents Sea. As such, it offers a comparable and comprehensible distribution of seabed habitats across Europe (i.e., EMODnet 2017, Populus et al. 2017). Such harmonized maps facilitate transboundary studies and management of seabed habitats (Populus et al. 2017). One of the current main applications is their consideration in the design of a representative network of marine protected areas, which constitutes a fundamental component of conservation and natural resources management policies (e.g., Dunn et al. 2018). In order to develop a well-designed MPA network in a given region, a broad representation of

its vulnerable habitats should be included, as well as the functional links between them (i.e., connectivity). However, this is seldom the case. Instead, networks are typically the result of an incremental ad-hoc process. For example, in the Azores archipelago the current network has been built over nearly four decades as result of (often) disjoint initiatives (Abecasis et al. 2015).

1.2 Regulation-based assessment of MPA networks

Several methods have been proposed to evaluate the current protection awarded by MPAs (Pomeroy et al. 2005, Horta e Costa et al. 2016, Rodríguez-Rodríguez et al. 2018). In this study, a regulation-based classification will be used to assess the potential of existing regulations in conserving the marine ecosystem (Horta e Costa et al. 2016, Figure 1.2). This system considers cumulative levels of disturbances and the multitude of combination of regulations and can be applied in single and multiple-zoning MPAs. Existing MPA regulations are used as proxies of impacts of (non-)extractive human activities on marine biodiversity and habitats (Horta e Costa et al. 2016). Such classification may be used complementarily to the IUCN categories that classify MPAs according to their conservation objectives (Horta e Costa et al. 2017).

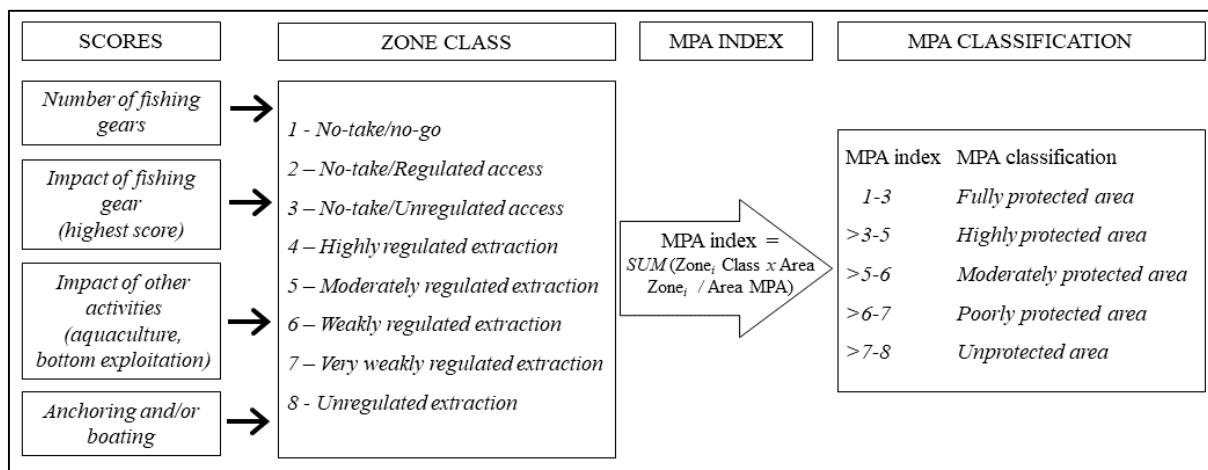


Figure 1.2. Regulation-Based Classification System for Marine Protected Areas Schema (adapted from Horta e Costa 2016)

1.3 The marine ecosystem and conservation in the Azores archipelago

The Azores archipelago is composed of nine volcanic islands, located along 600 km between 37°N and 40°N, crossing the Mid-Atlantic Ridge in the Northeast Atlantic. The Azores subregion of the Portuguese Exclusive Economic (Azorean EEZ) encloses an area of nearly 1 million km². Because of their volcanic origin, the islands and about 400 seamounts are flanked by slopes that drop steeply to the sea bottom (Morato et al. 2008). This large marine territory averages a depth of nearly 3000m and is dominated by a diverse mosaic of deep-sea habitats (e.g., Braga-Henriques et al. 2013; Tempera et al. 2013). Shallow areas (<200m depth) represent a mere 0.2% of the Azorean EEZ, generally consisting of narrow island shelves and a few eroded seamount tops (Figure 1.3). Most of the shoreline is exposed to heavy oceanic swells, except for some small bays and harbours that create sheltered environments (Wallenstein & Neto 2006; Tempera 2008). Growing and accumulated pressure of human uses have led to degrading marine ecosystems, including for example habitat loss, overexploitation, and pollution (Crain et al. 2009). This region is amongst the most impacted coastal ecoregions (Halpern et al. 2015) and environmental awareness is steadily growing. Since the first MPAs were created in the region in the 1980s, a multitude of MPA designations succeeded in different legal forms and with varying objectives (Abecasis et al. 2015). Presently, the Azores MPA network spreads out over the whole archipelago and extends from coastal areas out to the deep sea, including areas within the claimed extended continental shelf and currently beyond national jurisdiction. The Azores MPA network can be understood as a national contribute to basin-wide efforts of protecting representative sectors of the Mid-Atlantic ridge from mining (Dunn et al. 2018).

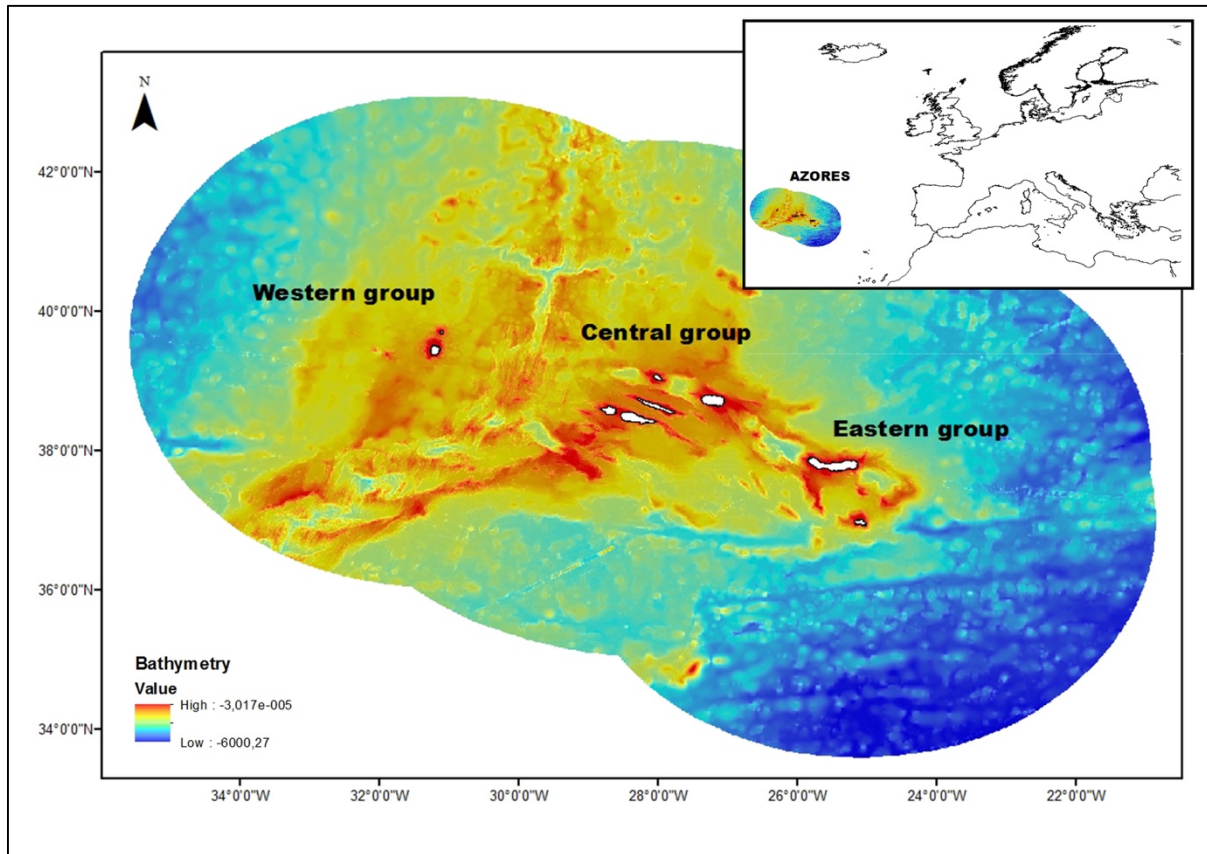


Figure 1.3. Map of the Azores region.

The Azores MPA network is supported by two distinct legal features for biodiversity conservation and resource management: the Island Natural Parks (INPs) and the Azores Marine Park (AMP) established between 2008 and 2011 (Abecasis et al. 2015). These MPAs vary in their legal forms and objectives (Abecasis et al. 2015), for example, they are used as a tool for biodiversity conservation and resource management implemented under regional initiatives or under different European Directives and Agreements, some of them being mandatory (e.g. OSPAR, Natura 2000, RAMSAR, Marine Strategy Framework Directive). However, most designated areas have not yet been fully implemented and management plans are still to be produced (Abecasis et al. 2015). Best knowledge available at the time of their creation often did not include relevant ecological information, such as on mobility in pelagic and adult stages of key species or the distribution of seabed habitats. In addition to these MPAs, other areas were designated a) for resource management (i.e., harvesting reserves and fisheries management areas), b) for the preservation of archaeological artefacts (i.e., archaeological parks), or c) have been promoted by local stakeholders. This diversity of designation

approaches and the absence of management plans create uncertainty on what in fact is protected and which restrictions do apply where (Abecasis et al. 2015) (Figure 1.4).

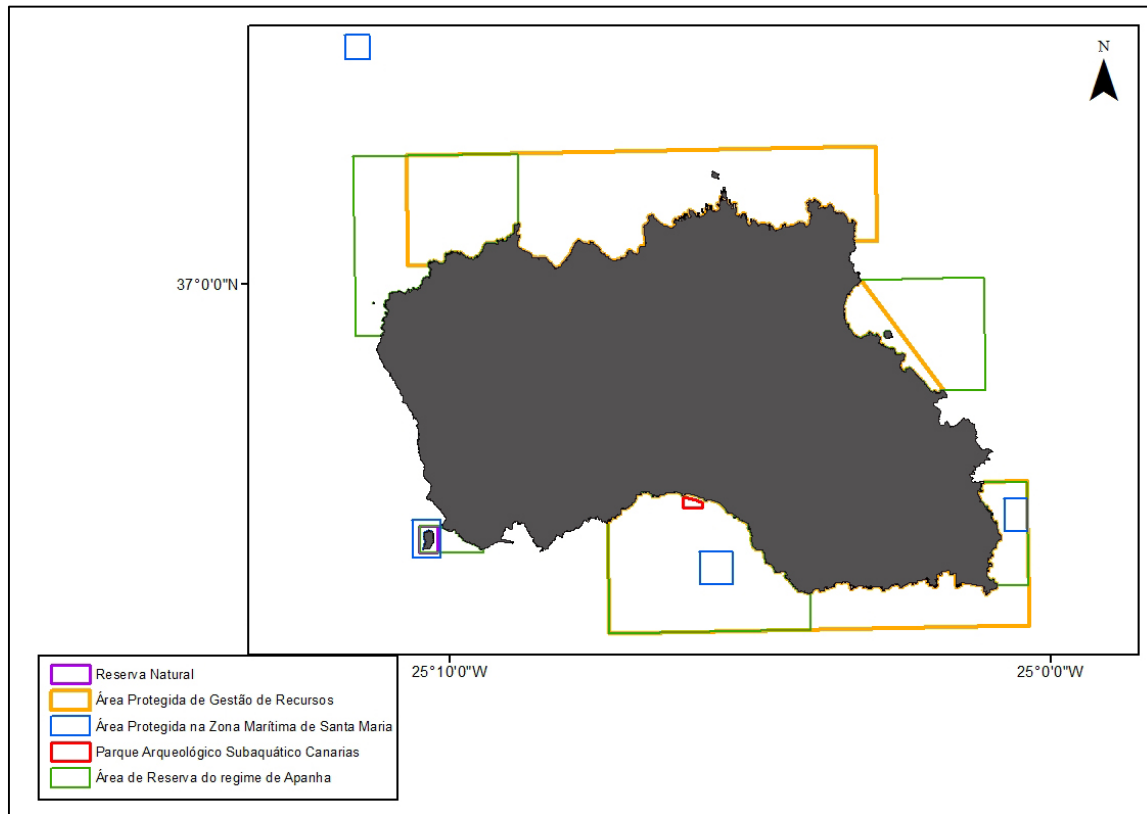


Figure 1.4. Example of different regulated marine areas in the island of Santa Maria.

New opportunities appear to carry out post-hoc assessments of the existing MPA network when new ecological information becomes available, such as the EMODnet seabed habitat coverage. This information can be used to improve conservation and management efforts concerning the Azores marine biodiversity and resources (see Abecasis et al. 2015). In this region, previous work evaluated the MPA coverage of infralittoral grounds (Schmiing et al. 2014, 2015; Amorim et al. 2015), however, important information such as the network's level of representativeness of the full breadth of shallow to deep water seabed habitats remains completely unassessed. This lacking data is fundamental to guide international policies, such as protecting 10% of coastal and marine protected areas by 2020 under the Aichi Biodiversity Target 11 (CBD Strategic Plan for Biodiversity 2010), and for ongoing conservation initiatives, such as the 'Promise of Sidney' recommendation of achieving 30% of protection by no-take zones (Wenzel et al. 2016).

1.4 Objectives

This study aims at: i) assessing the composition and representativeness of Azorean benthic habitats, as well as the biological zonation in the Azores subregion of the Portuguese Economic Exclusive Zone (EEZ), using datasets available from EMODnet Seabed Habitats portal (<https://www.emodnetseabedhabitats.eu/access-data/download-data/>); ii) evaluating and critically assess the effectiveness of the current MPA network in protecting the multitude of different habitats and biological zones in relation to European and world targets; and iii) supporting decision making by proposing potential adjustments to improve management and conservation efforts in the Azores.

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Chapter 2: Evaluating seabed habitat representativeness across a diverse marine protected area network on the mid-Atlantic ridge

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2.1 Abstract

Marine ecosystem-based management requires good spatial information on the distribution of marine species and habitats. Often, such information is limited to a few sampled locations and modelling techniques can be applied to produce predictive distribution maps. Harmonized broad-scale seabed habitat map was recently produced for Macaronesia under the EMODnet Seabed Habitats programme. We use this new information to produce an extent-based evaluation of the representativeness and level of protection conferred by the current Azores MPA network to the variety of benthic marine habitats found in this mid-ocean region. A more objective assessment of the protection provided to the habitats is obtained by applying a scoring system to the MPAs based on the number of permitted extractive and non-extractive human activities and their potential impact on marine biodiversity and habitats. Results show that habitats protected by the network are nearly entirely classified as highly protected. In total, 26 habitats (7 of which are endangered and 2 are rare ones) meet the Aichi Biodiversity Target 11 of having 10% of coastal and marine areas protected by 2020. Another 29 fail to meet even the lowest target (four on-shelf habitats and 25 deep-sea habitats), highlighting the need to extend protection of bathyal and abyssal habitats and applying adequate ecological coherence criteria. The approach utilized sets a standard that can be used wherever similar information is available, be it in other European regions or beyond.

2.2 Introduction

Marine ecosystem-based management has been endorsed as a most comprehensive and desirable approach to manage human activities in the seas and oceans for at least 3 decades (e.g., Fogarty and McCarthy 2014). Currently it is at the core of several marine spatial planning initiatives, European Directives and Blue Growth projects (Hoof et al. 2012; Lillebø et al. 2017).

A critical component underlying its decision-making processes is a good knowledge on the diversity, extent and distribution of seabed habitats. In line with this need, cataloguing and harmonized mapping of benthic habitats at regional scales has become a priority over the last two decades (Harris and Baker 2011; Vasquez et al. 2015; Populus et al. 2017) strengthening marine conservation efforts and assisting reporting obligations.

In Europe, advances towards mapping the seabed environments at broad scales have been made chiefly under the projects EUSeaMap, BALANCE, MESH and MESH-Atlantic (Al-Hamdani et al. 2007; Davies and Young 2008; Vasquez et al. 2015; Populus et al. 2017). Over more than one decade they developed and refined a method (named EUSeaMap) to model the broad-scale habitat distribution and compiled available seabed habitat maps for all European Seas. The resulting products are currently available as a seamless broad-scale seabed habitat map distributed via the EMODnet Seabed Habitats portal (<https://www.emodnet-seabedhabitats.eu/access-data/download-data/>). Seafloor environments are segmented according to the European Nature Information System (EUNIS) habitat classification - a comprehensive classification system which uses a series of environmental criteria to create and spatially delimit harmonised, hierarchical habitat classes (Davies et al. 2004). The resulting broad-scale map offers comparable and comprehensive maps of European seabed habitats covering from the Barents Sea to Macaronesia as well as adjacent seas like the Mediterranean and the Black Sea (Populus et al. 2017).

Such harmonized maps facilitate the study and management of seabed habitats across regions and countries (Populus et al. 2017). An obvious and key application is their consideration in the design of a representative marine protected area (MPA) network, which is a fundamental component of natural resource management and conservation policies and a need at ocean basin scales (e.g., Dunn et al. 2018). Ideally, a well-designed MPA network should represent the breadth of vulnerable habitats present in a given

region as well as the functional links between them (i.e., connectivity). Where MPA networks have been put together over decades via a succession of uncoordinated initiatives this is not always accomplished.

The Azores region is a remote sector of the wider Northeast Atlantic associated to an important Exclusive Economic Zone (EEZ) totalling nearly 1 million square kilometres and encompassing a varied mosaic of sublittoral to deep-sea habitats straddling the mid-Atlantic ridge. Multiple human uses have impacted marine ecosystems, notably via the intensive exploitation of some commercial marine species, habitat degradation and localised pollution (Santos et al. 1995; Abecasis et al. 2015). According to Halpern et al. (2015) its coastal environments are significantly impacted.

Since the first Azores MPAs were created in the 1980s, environmental awareness has steadily grown and a multitude of MPA designations have succeeded. Presently, the Azores MPAs are spread all over the archipelago and combine coastal and deep-sea environments, including areas within the claimed extended continental shelf. Apart from its role at national level, the Azores MPA network can also be seen as a contribution to basin-wide efforts of protecting representative sectors of the mid-Atlantic ridge from mining (Dunn et al. 2018).

The Azores MPA network is supported by two distinct types of legal designations related to biodiversity conservation and resource management: the Island Natural Parks (INPs) and the Azores Marine Park (AMP). These MPAs vary in their legal framing and include a series of areas aimed at either biodiversity conservation or local resource management goals (Abecasis et al. 2015). Part of them integrates broader nature protection networks such as Natura 2000, OSPAR, RAMSAR and Biosphere Reserve networks. In addition to these designations, other spatially-based measures are applied in the archipelago including a) fishing management areas, b) underwater archaeological parks, and c) small (non legally-binding) fishing closures promoted by local stakeholders.

Ecological knowledge available at the time of MPA creation was often incomplete. Exhaustive benthic habitat maps were often unavailable and information on the mobility of the pelagic and adult stages of targeted fish species has only started to be available in the last 15 years. As new comprehensive datasets become available, such as the EMODnet seabed habitat coverage, opportunities arise to conduct post-hoc assessments

of the existing MPA network and propose necessary amendments (see Abecasis et al. 2015).

Although earlier works assessed the MPA coverage of infralittoral grounds in the Azores (Amorim et al. 2015; Schmiing et al. 2014, 2015), the network's level of representativeness of the full breadth of shallow to deep-water seabed habitats that characterize the region remains unassessed. Such information is instrumental to guide regional, national and international action contributing towards conservation goals like the Aichi Biodiversity Target 11 (CBD Strategic Plan for Biodiversity 2010) of having 10% of coastal and marine areas protected by 2020 or the 'Promise of Sydney' recommendation (Wenzel et al. 2016) of achieving 30% of protection by no-take zones.

In this study the newest EUSeaMap broad-scale habitat map is used to evaluate the representativeness and level of protection awarded by the Azores MPA network to the variety of benthic marine habitats found in the Azores subregion of the Portuguese EEZ (hereafter named the Azores EEZ). For this purpose, the EUSeaMap habitat map is first extracted, refined and updated to the whole region. Secondly, a regulation-based classification is applied to the Azores MPA network with each zone/MPA being scored on the basis of the number of permitted extractive and non-extractive human activities and their potential impact on marine biodiversity and habitats.

Finally, both sets of information are combined to produce an extent-based analysis of the seabed habitats designated under the current MPA network accounting for the level of protection they statutorily afford from the regulations in place.

2.3 Material and Methods

2.3.1 *Study area*

The Azores archipelago is composed of nine volcanic islands, located along 600 km between 37°N and 40°N and straddling the Mid-Atlantic Ridge in the Northeast Atlantic (Figure 2.1). The Azores EEZ encloses an area of nearly 1 million km². Because of their volcanic origin, the islands and about 400 seamounts are flanked by slopes that drop steeply to the ocean floor (Morato et al. 2008). This large marine territory averages a depth of nearly 3000 m and is dominated by a diverse mosaic of deep-sea habitats (e.g., Braga-Henriques et al. 2013; Tempera et al. 2013). Shallow areas (<200m depth) represent a mere 0.2% of the Azores EEZ, generally consisting of narrow island shelves and some heavily eroded seamount tops. Most of the shoreline is exposed to strong oceanic swells. Sheltered environments are limited to a few small bays and artificial harbours (Wallenstein and Neto 2006; Tempera 2008).

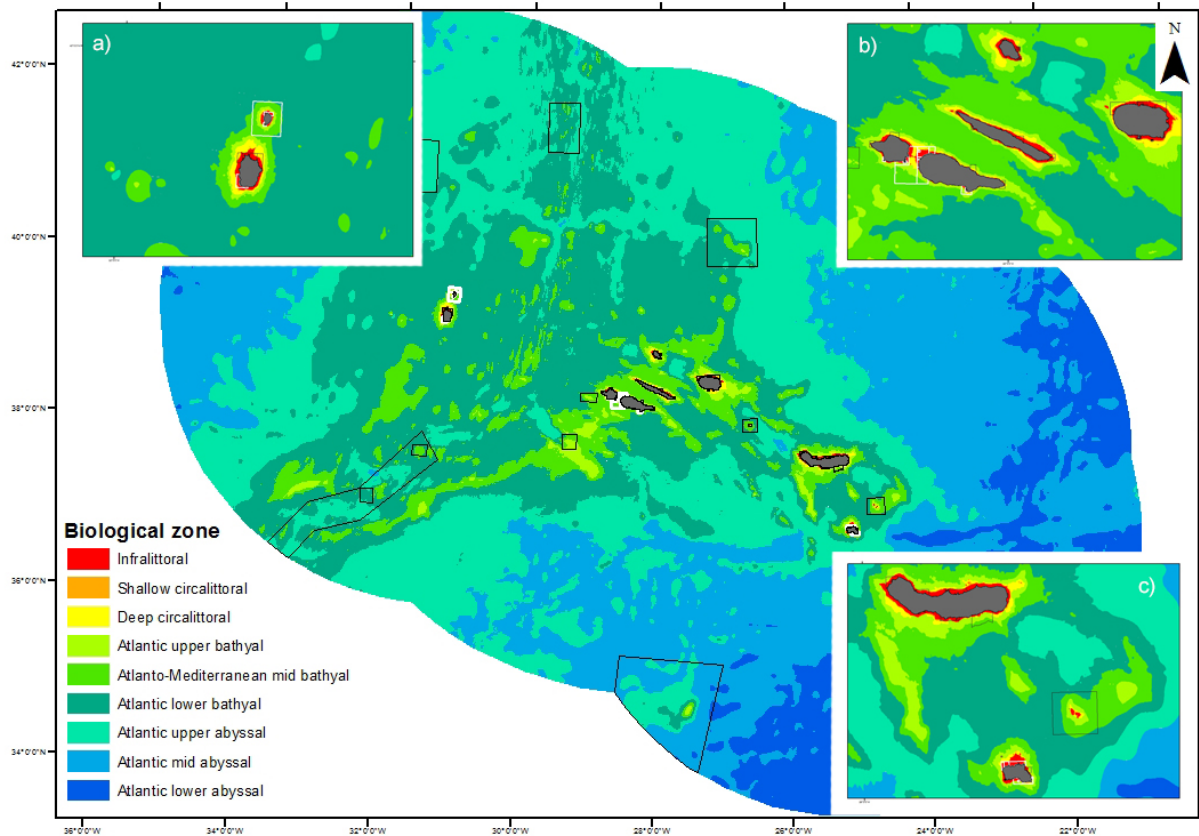


Figure 2.1. EMODnet-based biological zonation in the Azores subregion of the Portuguese EEZ as defined by light penetration, wave energy (wave base ratio) and bathymetry. Insets show a) the western group, b) the central group, and c) the eastern group. Rectangles represent current MPAs classified as moderately protected areas (white), highly protected areas (black), or fully protected areas (brown). Note: There is just one fully protected area (not visible at this scale). (Layer from EMODnet Seabed Habitats portal, <https://www.emodnet-seabedhabitats.eu/access-data/download-data/>).

2.3.1 The Azorean MPA network

Five types of legally-designated areas were considered as components of the Azores MPA network comprehending coastal and offshore areas. All of them have regulations that limit human activities directly affecting organisms associated with the seafloor and thereby contributing to achieving biodiversity conservation and living resource management goals. They consist of: 1) Island Natural Parks (INPs) generally aimed at protecting coastal areas (number MPAs=35); and 2) the Azores Marine Park (AMP) that encompasses offshore areas (n=11 inside the EEZ) (Abecasis et al. 2015). MPAs belonging to either an INP or the AMP are legally linked to goals of biodiversity conservation (Abecasis et al. 2015) and classified according to IUCN categories. Other designations include 3) harvest reserves (HRs), which specifically target the protection

of living benthic resources (n= 37); 4) fisheries management areas (FMAs), which aim to reduce conflicts by regulating fishing activity and access (n=12); and 5) archaeological parks (APs) designated to protect historical wrecks but which protect *de facto* the associated biodiversity via their prohibition of fishing and anchoring (n=5).

In some cases, those areas partly overlap in space with regulations adding up. This required merging or splitting of some MPAs prior to the analysis. All contiguous and overlapping areas were considered to be zones of the same MPA. If an MPA only partly laid inside the Azores EEZ then only this fraction was considered. MPAs in the extended continental shelf were thereby excluded from this study. The resulting set of polygons was subsequently used in the analysis.

2.3.2 Biological zones and habitat types

The biological zones are an intrinsic part of the EUNIS Marine Habitat Classification, which uses different environmental variables to define and classify habitats in a hierarchical system (Connor et al. 2004). The general depth-wise biological zonation of the Azores marine ecosystem was derived from a classification of raster layers representing light levels, wave energy (wave-base ratio) and bathymetry data (Vasquez et al. 2015). This zonation is presented in Table 2.1 and takes on board recent refinements proposed to the bathyal and abyssal thresholds (see Populus et al. 2017 for details).

Table 2.1. Variables and physical limits used for identifying biological zones in the Azores (adapted from Populus et al. 2017).

Biological zone	Variable used for thresholding	Physical limits	
		Upper	Lower
Infralittoral	Permanent immersion threshold and level of photosynthetically available radiation (PAR) at the seabed	Mean low water	0.4 mol. phot. m ² d ⁻¹
Shallow circalittoral	Wave base ratio (= wave length*/depth at seabed)	0.4 mol. phot.m ² .d ⁻¹	80 m
Deep circalittoral	Seabed depth and geomorphological thresholds	80 m	Shelf edge
Atlantic upper bathyal	Geomorphological and seabed depth thresholds	Shelf edge	600 m
Atlantic mid bathyal	Seabed depth thresholds	600 m	1300 m
Atlantic lower bathyal	Seabed depth thresholds	1300 m	2200 m
Atlantic upper abyssal	Seabed depth thresholds	2200m	3200 m
Atlantic mid abyssal	Seabed depth thresholds	3200 m	4300m
Atlantic lower abyssal	Seabed depth threshold	>4300 m	

* 3-year mean of percentile 90

Geospatial layers downloaded from the Seabed Habitats EMODnet portal on 17th October 2017 were used as the source of biological zone data and habitat data (Table 2.2). This seabed habitat map is endorsed by the European Union via the EMODnet programme and is the first product to provide a broad-scale full-coverage map of the region. The layer resulted primarily from the project MESH-Atlantic (see Vasquez et al. 2015), which fed upon earlier smaller-scale efforts to survey, catalogue and map habitats (e.g., projects MAROV, MARÉ, GEMAS, BIOTOPE, OGAMP, MARMAC).

Prior to the analysis, the EuSeaMap data layer (EMODnet 2017) was projected to the ‘PTRA 08/UTM zone 26N’ coordinate system and clipped using the maritime area contained between the shoreline and the 200 nautical mile limit of the Azores EEZ. Thin blank slivers adjacent to the coast were simply classed as part of the infralittoral zone. No seabed type could be attributed to them, so their areas contributed only to obtaining more accurate infralittoral extents. The coverage of each EUNIS habitat in each biological zone was then estimated. Habitats with less than 1% of coverage per zone were considered ‘rare’. All spatial analyses were performed in a Geographical Information System (GIS) using ArcGIS™ 10.1 (ESRI®).

Table 2.2. (3 pages) EUNIS Habitat types present in the Azores (Levels 2 to 4) (adapted from EMODnet 2017).

EUNIS Code	Habitat EUNIS	Biological zone	Substrate	Energy
A3.1	Atlantic and Mediterranean high energy infralittoral rock	Infralittoral	Rock or other hard substrata	High energy
A3.2	Atlantic and Mediterranean moderate energy infralittoral rock	Infralittoral	Rock or other hard substrata	Moderate energy
A3.3	Atlantic and Mediterranean low energy infralittoral rock	Infralittoral	Rock or other hard substrata	Low energy
A4.1	Atlantic and Mediterranean high energy circalittoral rock	Shallow circalittoral	Rock or other hard substrata	High energy
A4.12	Sponge communities on deep circalittoral rock	Deep circalittoral	Rock or other hard substrata	High energy
A4.2	Atlantic and Mediterranean moderate energy circalittoral rock	Shallow circalittoral	Rock or other hard substrata	Moderate energy
A4.27	Faunal communities on deep moderate energy circalittoral rock	Deep circalittoral	Rock or other hard substrata	Moderate energy
A4.3	Atlantic and Mediterranean low energy circalittoral rock	Shallow circalittoral	Rock or other hard substrata	Low energy
A4.33	Faunal communities on deep low energy circalittoral rock	Deep circalittoral	Rock or other hard substrata	Low energy
A5.13	Infralittoral coarse sediment	Infralittoral	Coarse sediment	NA

A5.14	Circalittoral coarse sediment	Shallow circalittoral	Coarse sediment	NA
A5.15	Deep circalittoral coarse sediment	Deep circalittoral	Coarse sediment	NA
A5.23/ A5.24	Infralittoral fine sand/Infralittoral muddy sand	Infralittoral	Sand	NA
A5.25/ A5.26	Circalittoral fine sand/Circalittoral muddy sand	Shallow circalittoral	Sand	NA
A5.27	Deep circalittoral sand	Deep circalittoral	Sand	NA
A5.33	Infralittoral sandy mud	Infralittoral	Sandy mud to muddy sand	NA
A5.34	Infralittoral fine mud	Infralittoral	Fine mud	NA
A5.35	Circalittoral sandy mud	Shallow circalittoral	Sandy mud to muddy sand	NA
A5.37	Deep circalittoral mud	Deep circalittoral	Sandy mud to muddy sand	NA
A5.43	Infralittoral mixed sediments	Infralittoral	Mixed sediment	NA
A5.44	Circalittoral mixed sediments	Shallow circalittoral	Mixed sediment	NA
A5.45	Deep circalittoral mixed sediments	Deep circalittoral	Mixed sediment	NA
A6	Deep-sea bed	Atlantic lower bathyal	Coarse sediment	NA
A6	Deep-sea bed	Atlantic upper bathyal	Coarse sediment	NA
A6	Deep-sea bed	Atlanto-Mediterranean mid bathyal	Coarse sediment	NA
A6.11	A6.11 : Deep-sea bedrock	Atlantic lower abyssal	Rock or other hard substrata	Low energy
A6.11	A6.11 : Deep-sea bedrock	Atlantic lower bathyal	Rock or other hard substrata	Low energy
A6.11	A6.11 : Deep-sea bedrock	Atlantic mid abyssal	Rock or other hard substrata	Low energy
A6.11	A6.11 : Deep-sea bedrock	Atlantic upper abyssal	Rock or other hard substrata	Low energy
A6.11	A6.11 : Deep-sea bedrock	Atlantic upper bathyal	Rock or other hard substrata	High energy
A6.11	A6.11 : Deep-sea bedrock	Atlantic upper bathyal	Rock or other hard substrata	Moderate energy
A6.11	A6.11 : Deep-sea bedrock	Atlantic upper bathyal	Rock or other hard substrata	Low energy
A6.11	A6.11 : Deep-sea bedrock	Atlanto-Mediterranean mid bathyal	Rock or other hard substrata	Low energy
A6.2	Deep-sea mixed substrata	Atlantic lower bathyal	Mixed sediment	NA
A6.2	Deep-sea mixed substrata	Atlantic mid abyssal	Mixed sediment	NA
A6.2	Deep-sea mixed substrata	Atlantic upper abyssal	Mixed sediment	NA
A6.2	Deep-sea mixed substrata	Atlantic upper bathyal	Mixed sediment	NA
A6.2	Deep-sea mixed substrata	Atlanto-Mediterranean mid bathyal	Mixed sediment	NA
A6.3	Deep-sea sand	Atlantic lower bathyal	Sand	NA
A6.3	Deep-sea sand	Atlantic mid abyssal	Sand	NA
A6.3	Deep-sea sand	Atlantic upper abyssal	Sand	NA
A6.3	Deep-sea sand	Atlantic upper bathyal	Sand	NA

A6.3	Deep-sea sand	Atlanto-Mediterranean mid bathyal	Sand	NA
A6.4	Deep-sea muddy sand	Atlantic lower abyssal	Sandy mud to muddy sand	NA
A6.4	Deep-sea muddy sand	Atlantic lower bathyal	Sandy mud to muddy sand	NA
A6.4	Deep-sea muddy sand	Atlantic mid abyssal	Sandy mud to muddy sand	NA
A6.4	Deep-sea muddy sand	Atlantic upper abyssal	Sandy mud to muddy sand	NA
A6.4	Deep-sea muddy sand	Atlantic upper bathyal	Sandy mud to muddy sand	NA
A6.4	Deep-sea muddy sand	Atlanto-Mediterranean mid bathyal	Sandy mud to muddy sand	NA
A6.5	Deep-sea mud	Atlantic lower abyssal	Fine mud	NA
A6.5	Deep-sea mud	Atlantic lower bathyal	Fine mud	NA
A6.5	Deep-sea mud	Atlantic mid abyssal	Fine mud	NA
A6.5	Deep-sea mud	Atlantic upper abyssal	Fine mud	NA
A6.5	Deep-sea mud	Atlantic upper bathyal	Fine mud	NA
A6.5	Deep-sea mud	Atlanto-Mediterranean mid bathyal	Fine mud	NA

2.3.3 Regulation-based assessment

The Azores MPAs/zones were categorized according to a regulation-based classification system (Horta e Costa et al. 2016) to harmonise protection levels. This system considers the different types of uses allowed inside MPAs and their potential impact on biodiversity and habitats to categorize the regulation strength in force to protect benthic habitats. First, zones were classified and scored based on 1) the number of fishing gears allowed (commercial and/or recreational) classified into six groups (0,]0-5],]5,10],]10-15],]15-20], >20); 2) the impact of fishing gear (commercial and/or recreational) ranging from 0 (no fishing allowed) to 9 (most destructive gear); 3) the presence of aquaculture and seabed exploitation grouped into 0= prohibited, 1= aquaculture or bottom exploitation permitted but sand extraction, mining or oil and gas exploitation forbidden, 2= all activities permitted with no restrictions; and 4) permission of recreational non-extractive activities (i.e. anchoring, and boating) grouped into 0= anchoring not allowed, 1= activities allowed but anchoring is fully regulated, and 2= boating/anchoring allowed but anchoring is only partially or not regulated (see Horta e Costa et al. 2016 for details). Table 2.3 summarises the scores attributed to the different types of fishing gear used by the commercial fleets and recreational fishermen as well as to other activities. Other highly impacting gears, such as bottom trawling, are prohibited inside almost the entire Azores EEZ (Council Regulation (EC) No 1568/2005; DLR No 29/2010/A, republished in Annex II to DLR No 30/2012/A). Harvest reserves did not receive the most restrictive score where they still allowed the exploitation of some species (i.e., octopus, certain

crustaceans, or algae). The classification system was adapted to reflect the current situation in the Azores, disregarding potential future uses which currently do not occur but are not forbidden either. Hence, sand extraction was the single seabed exploitation considered because other potential bottom impacting activities, such as commercial aquaculture, mining, and wind farms are currently absent in the Azores. The resulting classification varies between 1 (no-take/no-go) and 8 (unregulated extraction) (Horta e Costa et al. 2016). Zone classes were then used to obtain an MPA index (I_{MPA}) through the formula:

$$I_{MPA} = \sum_{z=1}^{n_z} C_{z_i} \times A_{z_i} / A_{MPA}$$

where C is the class of the zone (z) i , A_z the area of zone i , and A_{MPA} the total area of the respective MPA (Horta e Costa et al. 2016). This index is continuous and ranges from 1 to 8 and is finally used to classify each MPA under one of five categories ranging from ‘fully protected’ to ‘unprotected’. The extent of each biological zone and each EUNIS habitat type inside each MPA and its associated index were subsequently calculated.

Table 2.3. Summary of existing fishing gears for commercial and recreational fisheries, and other activities with corresponding scores in the Azores (adapted from Horta et al. 2016).

Fishing gear	Commercial fisheries	Recreational fisheries	Gear Score
Traps (lobster/octopus/crab)	Yes	No	4
Fish traps	Yes	No	6
Fixed fish traps "madrague"	No	No	6
Lines (jigs, hook and line, rod, troll)	Yes	Yes	5
Longlines (pelagic)	Yes	No	4
Longlines (bottom)	Yes	No	5
Purse seining (pelagic)	Yes	No	5
Purse seining (bottom)	No	No	9
Beach seines	No	No	8
Trawl (pelagic)	No	No	5
Trawl (bottom)	No	No	9
Gillnets	Yes	No	6
Trammel nets	No	No	8
Surrounding nets near shore	No	No	8
Drift nets	No	No	5
Dredges (bivalves)	No	No	7
Hand dredges (bivalves)	No	No	5
Spearfishing/diving	No	Yes	3
Cast nets	No	No	3
Intertidal hand captures	Yes	No	3
Hand harvesting	No	Yes	4
Other extractive activities			Score
Aquaculture or bottom exploitation not allowed			0
Aquaculture or bottom exploitation allowed, but not sand extraction			1
Both allowed with no restrictions or sand extraction allowed			2
Recreational activities	non-extractive		Score
No anchoring			0
Boating and/or anchoring allowed, but anchoring fully regulated			1
Boating and/or anchoring allowed, but anchoring is partially regulated or unregulated			2

2.4 Results

2.4.1 Biological zones and EUNIS habitat types

The biological zonation of the Azores EEZ established in the EUSeaMap layer is presented in Figure 2.1. The EEZ ($954.5 \times 10^3 \text{ km}^2$) is largely dominated by deep-sea habitat (25.4% bathyal and 74.4% abyssal) whereas shallow habitats (i.e. island shelf and shallow seamounts summits) represent a mere 0.2% (Table 2.4).

Table 2.4. (2 pages) Representativeness of biological zones (grey) and EUNIS habitats of the Azores Economic Exclusive Zone and percentage of the area included in the Azores MPA network per protection level.

Habitat Type	(% EEZ) Total area [Km ²]	% habitat per biological zone	% Fully protected	% Highly protected	% Moderately protected	% Total protected (Km ²)
Infralittoral	(0.1%) 814.2		0.1	25.6	17.2	42.9% (348.9)
A3.1	174.5	21.4	0	26.3	18.8	45.1% (78.6)
A3.2	122.8	15.1	0	27.1	16.1	43.2% (53.1)
A3.3	54.3	6.7	0	30.6	19.5	50.1% (27.2)
A5.13*	52.1	6.4	0	10.4	26.6	37.0% (19.2)
A5.23/A5.24	130.5	16.0	0	27.3	21.3	48.7% (63.5)
A5.33 ¹	1.0	0.1	0	0	0	0% (0)
A5.34 ¹	0.2	<0.1	0	0	0	0% (0)
A5.43	96.8	11.9	0.6	28.3	5.8	34.7% (33.6)
NI	182.0	22.4	<0.1	24.2	16.2	40.5% (73.7)
Shallow circalittoral	(<0.1%) 120.0		0	12.6	10.8	23.4% (28.1)
A4.1	5.8	4.9	0	9.2	24.8	34.1% (2.0)
A4.2	16.1	13.4	0	13.1	7.9	21.1% (3.4)
A4.3	19.9	16.6	0	9.2	22.5	31.7% (6.3)
A5.14*	14.1	11.8	0	8.8	3.2	12.0% (1.7)
A5.25/A5.26*	21.6	18.0	0	17.2	15.5	32.7% (7.0)
A5.35* ¹	0.5	0.5	0	15.6	0	15.6% (0.1)
A5.44*	38.3	31.9	0	12.4	5.1	17.5% (6.7)
NI	3.6	3.0	0	23.9	1.2	25.0% (0.9)
Deep circalittoral	(0.1%) 875.5		0	8.2	6.8	15.0% (131.2)
A4.12	16.7	1.9	0	29.8	16.7	46.5% (7.8)
A4.27	29.1	3.3	0	10.6	12.8	23.4% (6.8)
A4.33	294.3	33.6	0	9.0	11.3	20.2% (59.6)
A5.15*	134.6	15.4	0	5.5	1.6	7.2% (9.6)
A5.27*	112.7	12.9	0	6.4	7.6	13.9% (15.7)
A5.37* ¹	4.1	0.5	0	0	0	0% (0)
A5.45*	262.4	30.0	0	8.1	2.7	10.8% (28.2)
NI	21.7	2.5	0	5.7	10.6	16.2% (3.5)
Atlantic upper bathyal	(0.7%) 6283.3		0	7.6	2.0	9.6% (602.4)
A6	198.4	3.2	0	3.6	1.0	4.6% (9.2)
A6.11	1042.7	16.6	0	5.7	1.9	7.6% (79.5)
A6.2	2426.6	38.6	0	8.3	3.3	11.6% (280.8)
A6.3	2064.2	32.9	0	9.9	1.1	11.0% (226.3)
A6.41	44.1	0.7	0	14.7	0.1	14.8% (6.5)

A6.5	507.2	8.1	0	<0.1	0	<0.1% (0.1)
Atlanto-Mediterranean mid bathyal	(4.3%) 41108.1		0	5.3	0.6	5.8% (2400.5)
A61	386.1	0.9	0	25.5	0	25.5% (98.4)
A6.11	2853.4	6.9	0	7.2	0.2	7.4% (210.4)
A6.2	10052.1	24.5	0	9.5	1.3	10.8% (1088.1)
A6.3	5350.2	13.0	0	8.4	1.6	9.9% (530.8)
A6.41	290.8	0.7	0	1.2	3.9	5.1% (14.8)
A6.5	22175.5	53.9	0	2.0	<0.1	2.1% (457.9)
Atlantic lower bathyal	(20.4%) 194831.0		0	4.9	<0.1	4.9% (9610.4)
A61	118.4	0.1	0	<0.1	0	<0.1% (<0.1)
A6.11	2373.6	1.2	0	4.9	<0.1	4.9% (115.7)
A6.2	8358.2	4.3	0	11.7	0.1	11.8% (985.5)
A6.3	4510.2	2.3	0	9.3	0.1	9.4% (422.3)
A6.4	2348.0	1.2	0	0.2	0	0.2% (3.8)
A6.5	177122.7	90.9	0	4.6	<0.1	4.6% (8083.1)
Atlantic upper abyssal	(27.2%) 259985.2		0	5.2	0	5.2% (13456.7)
A6.111	1014.0	0.4	0	3.6	0	3.6% (36.2)
A6.21	1242.0	0.5	0	2.0	0	2.0% (25.2)
A6.31	549.8	0.2	0	<0.1	0	<0.1% (0.2)
A6.4	6197.2	2.4	0	0.3	0	0.3% (18.3)
A6.5	250982.2	96.5	0	5.3	0	5.3% (13376.8)
Atlantic mid abyssal	(32.1%) 306729.4		0	2.6	0	2.6% (7828.4)
A6.111	2635.8	0.9	0	0.9	0	0.9% (24.6)
A6.21	0.2	<0.1	0	0	0	0% (0)
A6.31	226.9	0.1	0	0	0	0% (0)
A6.4	11544.3	3.8	0	<0.1	0	<0.1% (<0.1)
A6.5	292322.3	95.3	0	2.7	0	2.7% (7803.8)
Atlantic lower abyssal	(15.1%) 143753.1		0	0.1	0	0.1% (199.9)
A6.111	352.2	0.2	0	0	0	0% (0)
A6.41	12.0	<0.1	0	0	0	0% (0)
A6.5	143388.9	99.7	0	0.1	0	0.1% (199.9)
Total area EEZ	954499.7	100	<0.1	3.6	0.1	3.6% (34606.5)
Shallow habitats	1809.7	0.2	<0.1	16.3	11.7	28.1% (508.2)
Deep sea habitats	952690.0	99.8	0	3.5	<0.1	3.6% (34098.3)
NI habitat in shallow zones	207.3	11.5	<0.1	22.3	15.4	37.7% (78.1)

NI = non-identified habitat; *threatened habitats listed in EU Red List; †rare habitats

A total of 28 unique EUNIS habitat types were identified in the Azores EEZ. This number rises to 55 if we consider the same habitat per biological zone, substrate and hydrodynamic exposure (when applicable) (Table 2.2, Figure 2.2; e.g., six EUNIS habitat A6.2 in Atlantic lower bathyal, Atlantic upper bathyal, Atlantic mid abyssal, Atlantic upper abyssal, Atlanto-Mediterranean mid bathyal biological zones). Shallow zones, although least represented, presented higher habitat diversity when compared with deeper zones. A decrease in habitat diversity per biological zone was observed, from eight habitats in the infralittoral to three habitats in the Atlantic lower abyssal (Figure 2.2). Almost the entire Azores EEZ was classified as deep-sea bed (99.8%, A6; Table 2.4), of which deep-sea mud (A6.5) dominated with almost 93% of coverage (72% at abyssal depths and 21% at bathyal ones). About 43.2% of the infralittoral was composed of hard

substrates (habitats A3.1, A3.2 and A3.3), of which 21.4% were classified with a high hydrodynamic exposure (Atlantic and Mediterranean high energy infralittoral rock – A3.1). Contrastingly, sediment was less common in the infralittoral (16.0% corresponding to infralittoral fine sand/infralittoral muddy sand – A5.23/A5.24). About 11.5% of the infralittoral had no associated substrate data (Table 2.4). The shallow circalittoral was dominated by circalittoral mixed sediment (A5.44; 31.9%) and circalittoral fine sand/circalittoral muddy sand habitats (A5.25/A5.26; 18.0%), whereas the deep circalittoral was mostly characterised by faunal communities on deep low energy circalittoral rock (A4.33, 33.6%) and deep circalittoral mixed sediments (A5.45, 30.0%). Sixteen rare habitats with less than 1% of coverage per zone were identified among all biological zones (Table 2.4).

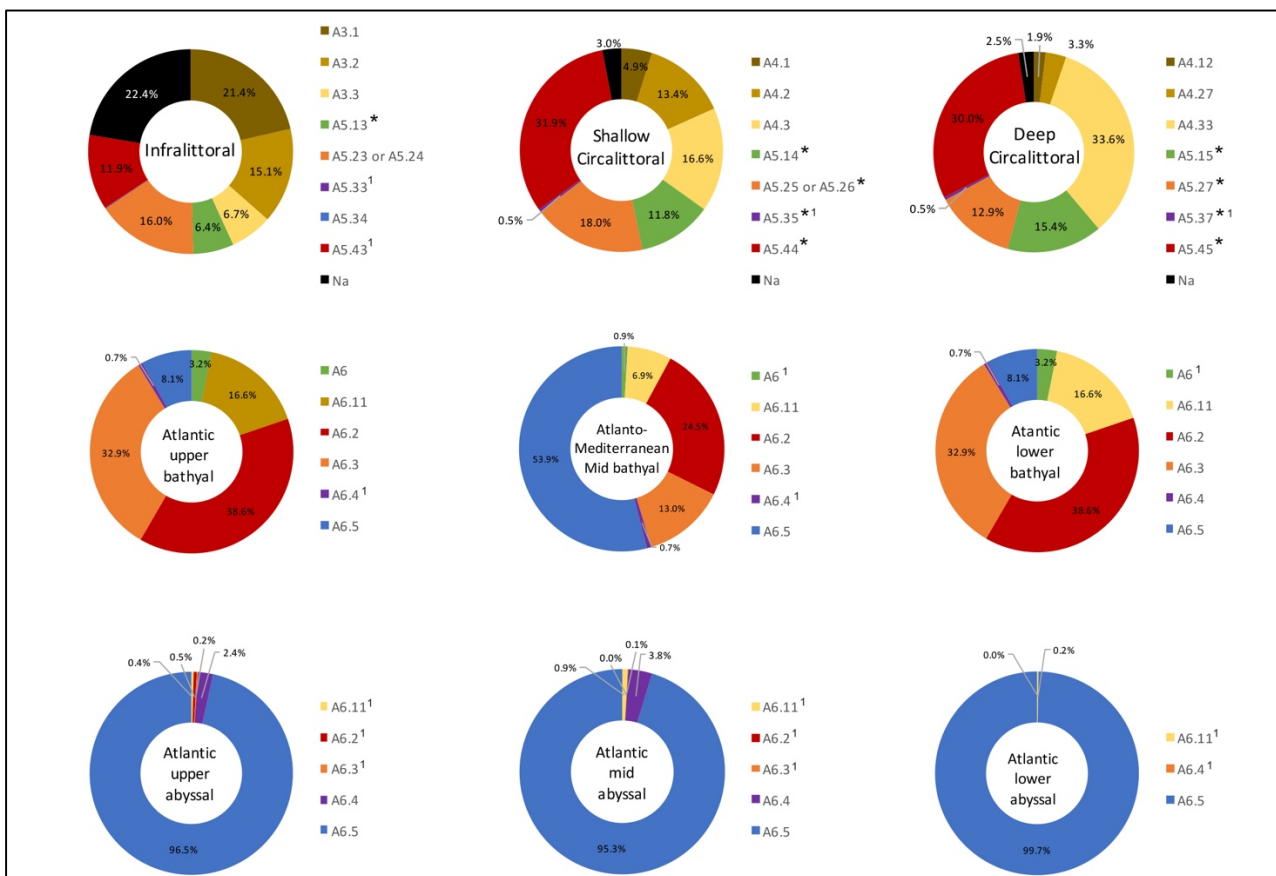


Figure 2.2. Representativeness of EUNIS habitats in the different biological zones of the Azores (NI = non-identified habitats, *threatened habitats listed in EU Red List, ¹rare habitats).

Nine of the identified EUNIS habitats are listed on the EU Red List of marine habitats, four as endangered (A5.25/A5.26, A5.27, A5.35, A5.37) and the remaining habitats (A5.13, A5.14, A5.15, A5.44, A5.45) as vulnerable (Gubbay et al. 2016). They occur in the infra- and circalittoral and cover small areas, ranging from 0.5 to 262.4 km² (Table 2.4).

2.4.2 Regulation-based classification of MPAs

The application of the different protection typologies results in a total of 100 legally-designated areas that cover a total of 34,606.5 km² and 3.6% of the Azores EEZ (Table 2.5, Figure 2.3). The “re-organized” network contained a final set of 46 MPAs composed of 93 zones. A single MPA encompassed up to 10 zones with distinct protection regime (Table 2.5) and a maximum of four overlapping zones (e.g. MPA ‘Azo24’). Most of the classified no-take zones (4 of 6) are legally-designated as, e.g. FMAs and APs, but are not part of the biodiversity-oriented MPAs (Table 2.5).

Table 2.5. (3 pages) List of MPA network and respective zones, adapted for this study. Overlapping and adjacent protected areas were edited and joined to the same MPA.

MPA code	Nr. of zones	Zone Code	Year	Nr. fishing gears	Max. zone gear score	Max. other activities score	Max. other recreational. uses score	Zone class	Zone Classification	MPA index	MPA Classification	Area km ²
Azo01	1	PMA06	2011	5	5	0	2	4	Highly regulated extraction	4.0	Highly protected	2689.2
Azo02	1	PMA07	2011	5	5	0	2	4	Highly regulated extraction	4.0	Highly protected	2607.0
Azo03	1	PMA05	2011	4	5	0	2	4	Highly regulated extraction	4.0	Highly protected	4093.1
Azo04	1	PMA14	2016	2	5	0	1	4	Highly regulated extraction	4.0	Highly protected	242.0
Azo05	2	PMA01	2011	4	5	0	2	4	Highly regulated extraction	5.0	Highly protected	16.2
Azo05	2	PMA11	2011	7	5	0	2	5	Moderately regulated extraction	5.0	Highly protected	329.8
Azo06	1	PMA15	2016	7	5	0	2	5	Moderately regulated extraction	5.0	Highly protected	369.7
Azo07	3	PMA02	2011	4	5	0	2	4	Highly regulated extraction	4.9	Highly protected	265.4
Azo07	3	PMA03	2011	4	5	0	2	4	Highly regulated extraction	4.9	Highly protected	302.1
Azo07	3	PMA13 - EEZ	2016	6	5	0	2	5	Moderately regulated extraction	4.9	Highly protected	8591.7
Azo08	1	PMA12 - EEZ	2016	6	5	0	2	5	Moderately regulated extraction	5.0	Highly protected	13620.4
Azo09	4	COR02	2008	9	6	2	2	6	Weakly regulated extraction	6.0	Moderately protected	249.8
Azo09	4	COR02-COR(A)	2008	9	6	0	2	5	Moderately regulated extraction	6.0	Moderately protected	2.2
Azo09	4	COR02-COR(B)	2008	9	6	2	2	6	Weakly regulated extraction	6.0	Moderately protected	3.5
Azo09	4	COR02-COR(C)	2008	9	6	0	2	5	Moderately regulated extraction	6.0	Moderately protected	2.5
Azo10	4	FLO(A)	2014	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	13.4
Azo10	4	FLO09	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	14.2
Azo10	4	FLO09-FLO(A)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	6.3
Azo10	4	FLO09-FLO(B)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	19.3
Azo11	2	FLO(C)	2014	9	6	2	2	6	Weakly regulated extraction	6.0	Moderately protected	17.2
Azo11	2	FLO(C)-PASS	2014	0	0	0	1	2	No-take/Regulated access	6.0	Moderately protected	0.2
Azo12	1	GRA08-GRA(A)	2014	7	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	2.8
Azo13	1	AREPZMIG(BF)	2016	3	5	0	2	4	Highly regulated extraction	4.0	Highly protected	0.0
Azo14	3	GRA(B)	2014	9	6	0	2	5	Moderately regulated extraction	4.7	Highly protected	4.8

Azo14	3	GRA(B)-AREPZMIG(IP)	2014	3	5	0	2	4	Highly regulated extraction	4.7	Highly protected	0.3
Azo14	3	GRA02-GRA(B)-AREPZMIG(IP)	2008	3	5	0	2	4	Highly regulated extraction	4.7	Highly protected	2.1
Azo15	3	GRA(C)	2014	9	6	0	2	5	Moderately regulated extraction	4.1	Highly protected	1.9
Azo15	3	GRA01-GRA(C)-AREPZMIG(IB)	2008	3	5	0	2	4	Highly regulated extraction	4.1	Highly protected	1.3
Azo15	3	GRA07-GRA(C)	2008	0	0	0	2	3	No-take/Unregulated access	4.1	Highly protected	1.4
Azo16	1	GRA(D)	2014	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	1.0
Azo17	2	SJO(A)	2014	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	0.1
Azo17	2	SJO10-SJO(A)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	2.1
Azo18	1	SJO11-SJO(D)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	2.5
Azo19	1	SJO12-SJO(B)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	8.7
Azo20	2	SJO(C)	2014	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	5.9
Azo20	2	SJO13-SJO(C)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	6.0
Azo21	1	FAI13-FAI(B)	2008	8	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	8.9
Azo22	1	FAI12-FAI(A)	2008	8	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	5.0
Azo23	2	FAI(D)	2014	9	6	2	2	6	Weakly regulated extraction	5.4	Moderately protected	0.8
Azo23	2	FAI11-FAI(D)	2008	8	6	0	2	5	Moderately regulated extraction	5.4	Moderately protected	1.3
Azo24	10	FAI01-FAI(C)-AREPZMIFP(MG)	1980	0	0	0	0	1	No-take/No-go	5.7	Moderately protected	0.1
Azo24	10	FAI10	2008	9	6	2	2	6	Weakly regulated extraction	5.7	Moderately protected	154.8
Azo24	10	FAI10-FAI(C)	2008	9	6	2	2	6	Weakly regulated extraction	5.7	Moderately protected	16.5
Azo24	10	FAI10-FAI(C)-AREPZMIFP(MG)	2008	3	5	0	2	4	Highly regulated extraction	5.7	Moderately protected	2.2
Azo24	10	PIC(A)	2014	9	6	0	2	5	Moderately regulated extraction	5.7	Moderately protected	11.7
Azo24	10	PICO(22)	2008	9	6	0	2	5	Moderately regulated extraction	5.7	Moderately protected	30.5
Azo24	10	PICO22-PIC(A)	2008	9	6	0	2	5	Moderately regulated extraction	5.7	Moderately protected	32.8
Azo24	10	PICO22-PIC(A)-AREPZMIFP(BB)	2008	0	0	0	2	3	No-take/Unregulated access	5.7	Moderately protected	1.0
Azo24	10	PICO22-PIC(A)-AREPZMIFP(IM)	2008	3	5	0	2	4	Highly regulated extraction	5.7	Moderately protected	2.4
Azo24	10	PICO22-PIC(A)-AREPZMIFP(IM)-PASBC	2008	1	5	0	1	4	Highly regulated extraction	5.7	Moderately protected	0.1
Azo25	1	PIC(B)	2014	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	9.3
Azo26	1	PICO21-PIC(C)	2008	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	6.0
Azo27	2	PIC(D)	2014	9	6	2	2	6	Weakly regulated extraction	5.9	Moderately protected	14.1
Azo27	2	PICO20-PIC(D)	2008	9	6	0	2	5	Moderately regulated extraction	5.9	Moderately protected	1.5
Azo28	1	TER(A)	2014	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	27.7
Azo29	5	TER(B)	2014	9	6	0	2	5	Moderately regulated extraction	4.9	Highly protected	42.7
Azo29	5	TER(B)-AREPZM(QR)	2018	2	5	0	2	4	Highly regulated extraction	4.9	Highly protected	2.6
Azo29	5	TER15-TER(B)	2011	9	6	0	2	5	Moderately regulated extraction	4.9	Highly protected	1.8
Azo29	5	TER15-TER(B)-AREPZM(QR)	2011	2	5	0	2	4	Highly regulated extraction	4.9	Highly protected	1.8

Azo29	5	TER19-TER(B)	2011	9	6	0	2	5	Moderately regulated extraction	4.9	Highly protected	0.4
Azo30	1	TER18	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	0.0
Azo31	5	PASBA	2015	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	0.1
Azo31	5	TER(E)	2014	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	2.7
Azo31	5	TER(E)-PASBA	2014	7	6	0	1	5	Moderately regulated extraction	5.0	Highly protected	0.5
Azo31	5	TER20-TER(E)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	0.4
Azo31	5	TER20-TER(E)-PASBA	2011	7	6	0	1	5	Moderately regulated extraction	5.0	Highly protected	0.0
Azo32	1	TER17-TER(D)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	1.1
Azo33	1	TER16-TER(C)	2011	8	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	1.8
Azo34	1	SMG23-SMG(A)	2011	8	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	19.5
Azo35	1	SMG22-SMG(B)	2011	8	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	15.0
Azo36	1	SMG21-SMG(C)	2011	8	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	23.1
Azo37	1	SMG20-SMG(D)	2011	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	3.6
Azo38	1	PASD	2012	0	0	0	1	2	No-take/Regulated access	2.0	Fully protected	0.6
Azo39	2	SMG(E)	2014	9	6	0	2	5	Moderately regulated extraction	4.2	Highly protected	3.5
Azo39	2	SMG19-SMG(E)	2008	2	4	0	2	4	Highly regulated extraction	4.2	Highly protected	13.3
Azo40	1	AREPAM(RQ)	2016	6	5	0	2	5	Moderately regulated extraction	5.0	Highly protected	65.6
Azo41	1	SMA01	2003	1	5	0	2	4	Highly regulated extraction	4.0	Highly protected	523.9
Azo42	1	APZMISM(BA)	2014	2	5	0	1	4	Highly regulated extraction	4.0	Highly protected	0.4
Azo43	3	SMA12	1987	9	6	2	2	6	Weakly regulated extraction	5.6	Moderately protected	17.9
Azo43	3	SMA12-STM(A)	1987	9	6	0	2	5	Moderately regulated extraction	5.6	Moderately protected	6.7
Azo43	3	STM(A)	2014	9	6	0	2	5	Moderately regulated extraction	5.6	Moderately protected	5.5
Azo44	2	SMA11-STM(B)	1987	8	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	1.8
Azo44	2	STM(B)	2014	9	6	0	2	5	Moderately regulated extraction	5.0	Highly protected	5.7
Azo45	4	APZMISM(IV)	2014	2	5	0	1	4	Highly regulated extraction	4.4	Highly protected	0.3
Azo45	4	SMA02-STM(E)-APZMISM(IV)	2012	2	5	0	1	4	Highly regulated extraction	4.4	Highly protected	0.2
Azo45	4	STM(E)	2018	9	6	0	2	5	Moderately regulated extraction	4.4	Highly protected	0.4
Azo45	4	STM(E)-APZMISM(IV)	2018	2	5	0	1	4	Highly regulated extraction	4.4	Highly protected	0.1
Azo46	6	SMA13	1987	9	6	2	2	6	Weakly regulated extraction	5.8	Moderately protected	5.7
Azo46	6	SMA13-SMT(C)	1987	9	6	0	2	5	Moderately regulated extraction	5.8	Moderately protected	1.9
Azo46	6	SMA13-SMT(C)-APZMISM(BM)	1987	2	5	0	1	4	Highly regulated extraction	5.8	Moderately protected	0.5
Azo46	6	SMA13-SMT(D)	1987	9	6	2	2	6	Weakly regulated extraction	5.8	Moderately protected	12.7
Azo46	6	SMA13-SMT(D)-APZMISM(BP)	1987	2	5	0	1	4	Highly regulated extraction	5.8	Moderately protected	0.7
Azo46	6	SMA13-STM(D)-PASC	1987	0	0	0	1	2	No-take/Regulated access	5.8	Moderately protected	0.1

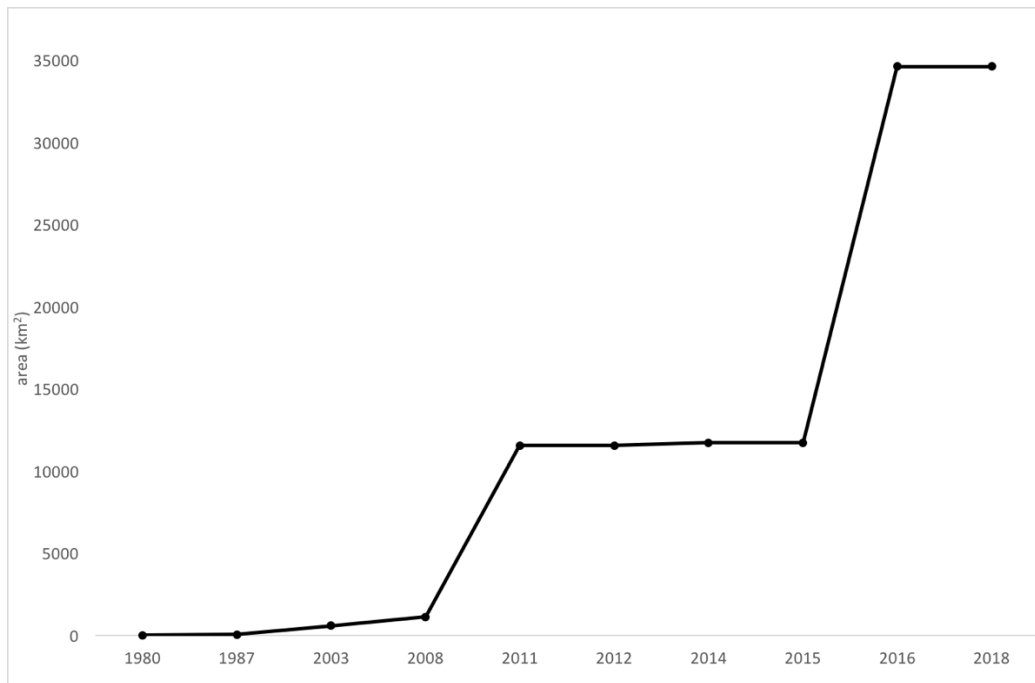


Figure 2.3. Temporal evolution of the total protected marine area in the Azores archipelago; values include all five types of designated MPAs in the Region (see text for explanation).

The application of the regulation-based classification system resulted in three types of MPAs ranging from “fully-protected area” to “moderately-protected area” (Table 2.5, Figure 2.1), with an MPA index ranging from 2 to 6. The majority of MPAs (98.3%, corresponding to 3.6% of the EEZ) fell into the highly-protected category and only 1.7% (0.1% of the EEZ) was covered by moderately-protected areas. Less than 0.1% of the MPAs were considered to be fully protected (<0.01% of the EEZ) (Table 2.4). No poorly-protected or unprotected areas were identified, mostly due to the relatively low (9) maximum number of fishing gears allowed in a given zone across the Azores MPA network (Table 2.5).

2.4.3 Biological zone and habitat coverage by the MPA network

The MPA network covered 42.9% of the total infralittoral zone, 23.4% of the shallow circalittoral, 15.0% of the deep circalittoral and only 5.2% of the bathyal zone and 3.0% of the abyssal zone contained in the Azores EEZ (Table 2.4, Figure 2.4). Shallow habitats with no associated seabed data in the Azores MPA network represented 37.7% (Table 2.4).

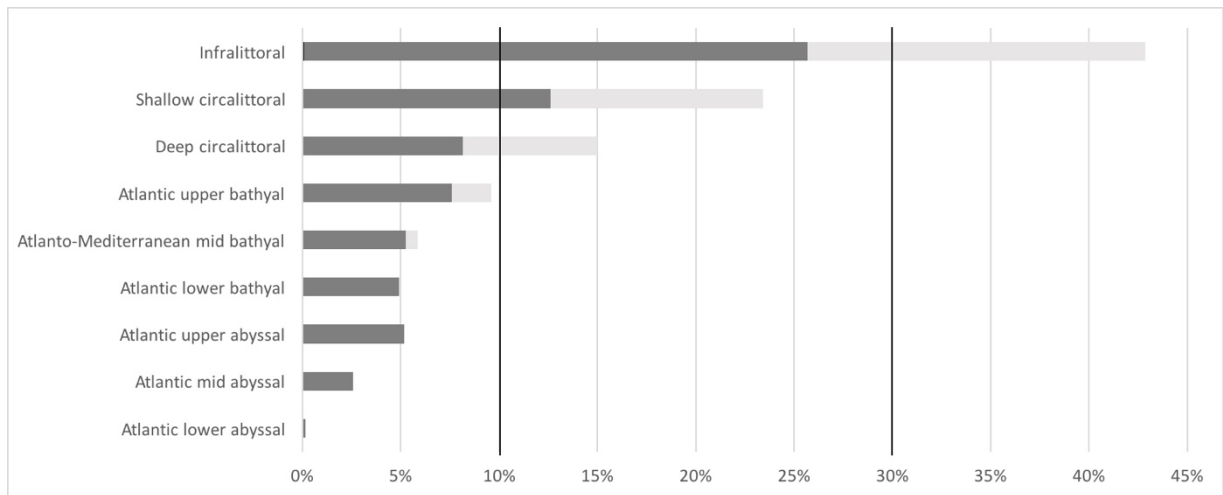


Figure 2.4. Representativeness (in %) of each biological zone in the Azores MPA network, classified by level of protection. 10 and 30% thresholds represent Aichi targets and Sydney agreements, respectively. The colour code represents level of protection: moderately protected (light grey), highly protected (dark grey) and fully protected (black). Note: The only fully protected area covers a mere 0.1% of the infralittoral.

Fully protected areas encompassed a single habitat (infralittoral mixed sediments (A5.43) in a single MPA; Tables 2.4, 2.5). Atlantic and Mediterranean low energy infralittoral rock habitat (A3.3) received the widest protection in the region (> 50% of its extent, 30.6% as highly protected and 19.5% as moderately protected) (Table 2.4). On the other hand, some of the identified EUNIS habitat types were either not covered by the MPA network (seven habitats, all considered as rare habitats) or nearly absent (<1%, eight habitats) (Table 2.4, Figure 2.5). Furthermore, just 26 of the 55 habitats meet Aichi targets with more than 10% of their total area protected (Figure 2.5).

Biological zone	Rock (HE)	Rock (ME)	Rock (LE)	Coarse Sediment	Fine Mud	Mixed Sediment	Sand	Sandy Mud/Muddy Sand
Infralittoral	A3.1	A3.2	A3.3	A5.13*	A5.34 ¹	A5.43	A5.23/A5.24	A5.33 ¹
Shallow circalittoral	A4.1	A4.2	A4.3	A5.14*		A5.44*	A5.25/A5.26*	A5.35* ¹
Deep circalittoral	A4.12	A4.27	A4.33	A5.15*		A5.45*	A5.27*	A5.37* ¹
Atlantic upper bathyal	A6.11	A6.11	A6.11	A6	A6.5	A6.2	A6.3	A6.4 ¹
Atlanto-Mediterranean mid bathyal			A6.11	A6 ¹	A6.5	A6.2	A6.3	A6.4 ¹
Atlantic lower bathyal			A6.11	A6 ¹	A6.5	A6.2	A6.3	A6.4
Atlantic upper abyssal			A6.11 ¹		A6.5	A6.2 ¹	A6.3 ¹	A6.4
Atlantic mid abyssal			A6.11 ¹		A6.5	A6.2 ¹	A6.3 ¹	A6.4
Atlantic lower abyssal			A6.11 ¹		A6.5			A6.4 ¹

Figure 2.5. Representativeness of each EUNIS habitat per biological zone in the Azores MPA network (*threatened habitats listed in EU Red List, ¹ rare habitat). The colour code represents % of protection: White >30%, light grey 10-29%, dark grey 1-9% and black >1%.

Coverage by the MPA network of threatened habitats in the infra-/ and circalittoral (Gubbay et al. 2016) ranged from 7.2 to 37.0%, the only exception being deep circalittoral mud habitat (A5.37) which was not covered at all (Figure 2.5). When considering the Aichi targets, just two threatened habitats (A5.15 - 7.2% and A5.37 - 0%) do not reach 10% of protection, but just three rare habitats have more than 10% of its total coverage protected i.e., mid-bathyal deep-sea bed (A6 – 25.5%), circalittoral sandy mud habitat (A5.35 – 15.6%) and upper bathyal deep-sea muddy sand (A6.4 – 14.8%).

2.5 Discussion

2.5.1 *Marine habitats and biological zones in the Azores*

The Azores region shares the typical geomorphology of oceanic archipelagos, with narrow shelves and large deep-sea extents. This character is markedly reflected in its broad-scale habitat identity (this study; Vasquez et al. 2015; Peran et al. 2016), with shallower biological zones (<200m) apparently more diverse in substrate types and encompassing more rocky substrates than deeper biological zones. It is worth noting that the vast dominance of rocky substrate observed along the Azores shorelines is not reflected underwater with rocky substrates representing less than 50% of the submerged shelf areas. Such result is corroborated by detailed studies of some Azorean island shelves using multibeam sonars (Tempera 2008; Quartau et al. 2010). On the other hand, the observed decrease in habitat richness from shallow to deep areas should be partly an artefact of the scarcity of full-coverage surveys interpreted for substrate type in the bathyal and abyssal zones. This is reflected in the low confidence score given to the habitats mapped by EUSeaMap for these biological zones.

The Azores region also holds a variety of habitats of priority for conservation. This includes 9 identified habitats listed on the EU Red List of marine habitats, but also various other priority habitats from the Habitats Directive and OSPAR Convention. Some of these habitats may not have been identified individually but are contained in other habitats because of the hierarchical structure and the broader scale used in the EUNIS habitat classification. For example, habitat A6.11 may include the Natura 2000 priority habitat “1170 – reefs” and the OSPAR habitats “coral gardens”, “*Lophelia pertusa* reefs” and “deep-sea sponge aggregations”. The same applies to: A3.1/A3.2/A3.3/A4.1/A4.2/A4.3 (including 1160 – large shallow inlets and bays and 1170 – reefs); A.5 (including maerl habitats – A5.51); A5.1/A5.2/A5.3/A5.4 (including 1160 – large shallow inlets and bays); A6.1 (including 1170 – reefs); A6.2 (including 1170 – reefs and coral gardens); A6.3 (including deep-sea sponge aggregations and coral gardens); A6.4 (including coral gardens); A6.5 (including deep-sea sponge aggregations and coral gardens) (OSPAR 2008; EEA 2018). Areas with no associated substrate type (including nearly a quarter of the total infralittoral area) or with low confidence (as deep-sea substrates may contain important habitats. Filling these knowledge gaps and producing a cross-over table between classifications and protected habitats should thus be a priority.

2.5.2 *The Azores MPA network*

This study provides an integrated view of the MPA network and a clearer evaluation of the actual levels of protection across the total study area as it categorizes MPAs based on their regulations. By concatenating the effects of marine regulations emanating from different legislation over each zone, it manages to identify non biodiversity-related designations (e.g. FMAs and APs) that in reality can offer higher levels of protection to benthic habitats than traditional MPA designations. This is emphasized by the fact that most no-take zones (4 of the 6) as well as the single fully-protected area are safeguarded via this kind of spatially-based measures.

Different factors explain why most of the areas in the Azores MPA network came out as highly-protected: 1) no more than 10 fishing gears are allowed/used in the Azores waters altogether (in comparison to 21 in Horta e Costa et al. 2016), and only a maximum of nine gears are authorized for a given zone; 2) the highest score of existing fishing gears is 6 (fish traps and gillnets) from a maximum of 9, which makes them of comparatively small potential for damaging benthic habitats and biodiversity (Horta e Costa et al. 2016); and 3) the absence of commercial aquaculture and seabed exploitation apart from sand extraction. Importantly, the scores of the regulation-based MPA classification adopted here are not fixed and may change whenever regulations for a given area are adapted or new areas are designated. For example, there was no operating aquaculture farm at the time of the preparation of this manuscript but areas for on-shelf aquaculture (mainly for algae) have already been designated around four islands, with some already holding experimental work. Furthermore, regulation-based methodologies can complement objective-based IUCN methodologies, providing more transparency to the assessment of marine conservation goals (Dudley et al. 2017; Horta e Costa et al. 2017).

Results show that, in the future, if 1) no aquaculture and seabed exploitation and 2) no other fishing gears are allowed in the Azores (at least inside of the MPAs), then the network will keep its moderately to fully protected status.

It is also worth noting that few of the Azores MPAs explicitly include some sort of zoning (i.e. MPA Azo05 and Azo07). Other MPAs appear to have a zoning scheme, but this mostly results from the overlapping approach used in this study or by having adjacent MPAs with different regulations (e.g., Azo24) than being the outcome of an objectively-

designed zoning. Some studies from the Azores also suggest that a lack of MPA management/implementation is (partly) responsible for clearer evidence of MPA effectiveness (Batista and Cabral 2016; Afonso et al. 2018). Management effectiveness was not integrated in the present study but should be in future studies, as well as criteria linked to the connectivity traits of targeted species.

2.5.3 Representativeness of biological zones in the MPA network

The fact that the different biological zones are not equally represented in the Azores MPA network is a major highlight of this study. The Azores are clearly dominated by deep-sea zones (bathyal and abyssal) mostly consisting of muddy seabed (if considering the low confidence EMODnet seabed type information). Nevertheless, shallow areas (infralittoral and circalittoral) are more represented in the network both in terms of diversity and proportions either at the biological zone or habitat level (Figures 2.4, 2.5). In fact, shallow biological zones actually reach Aichi targets (i.e., infralittoral, 42.9%; shallow circalittoral 23.4% and deep circalittoral 15%) (Figure 2.4).

This unbalance stems mostly from MPAs having historically been most frequently designated on the island shelves than on the vast deep-sea area (Santos et al. 1995; UNEP-WCMC 2008). It was the creation of the Azores Marine Park in 2011 and its revision in 2016 that substantially increased the deep-sea areas affording protection (Figure 2.3).

The broad unbalance between shallow and deep-sea protection also spreads into a finer habitat level. Our study highlights that 29 of the 55 habitats identified for the region are insufficiently covered by MPAs (four shallow habitats and 25 deep-sea habitats) (Figure 2.5), failing to reach internationally set targets such as the CDB. Although MPA coverage has recently increased in the Azores (23,065 km² newly designated in the last five years), attaining the 10% target within the EEZ by 2020 would still require considerably accelerating these efforts to designate an additional 610,000 km².

Furthermore, this study highlights that the single fully-protected area currently existing in the Azores (Azo38) only protects one habitat (A5.43) and only a mere 0.6% of its distribution in the region. Results show that most Azores MPAs probably fail to provide robust protection to benthic habitats and biodiversity because extraction of living and non-living resources is (i) poorly regulated, (ii) hardly any no-take areas exist, and (iii) most MPAs are not completely implemented (Abecasis et al. 2015; Afonso et al. 2018).

This contrasts with international conservation goals (see Wenzel et al. 2016), which target fully-protected no-take zones. With a small size single no-take MPA and six no-take zones integrated in the remaining MPAs, biodiversity protection becomes unachievable (Costello and Ballantine 2015). To reach this objective, the existing legislation would need to be revised and manage/exclude fisheries and extraction of non-living resources in wider areas (Amorim et al. 2015).

In addition, if the structure of the network itself is considered, the MPA zoning was not designed specifically taking into account ecological criteria linked to connectivity and detailed information on species/habitat distribution, but rather more general ideas based on best available knowledge and frequently building on previously designated areas.

The inclusion of threatened habitats in the MPA network is rather representative, with 7 out of the 9 Red List habitats receiving over 10% protection. However, some rarer habitats are underrepresented in the MPA network. For example, there is no protection of deep circalittoral mud (A5.37). This is probably also the case for maerl habitats, which are listed as threatened and/or in decline (OSPAR 2008) but still need to be properly mapped and included in EMODnet Seabed Habitats products. As highlighted by the results of Rebelo et al. (2018), in the Azores, this will probably require dedicated surveys of upper circalittoral areas located beyond 40m depths. As regards to the deep-sea, until higher levels of confidence concerning substrate distribution are achieved, we recommend that MPA network design resorts to habitat complexes coverage (seamounts, depth zone) whilst applying criteria of ecological connectivity between designated areas.

2.5.4 Conclusions

Assessing the protection conferred by the Azores MPA network to the diversity of broad-scale benthic habitats present in the region permitted evaluating the accomplishments of the network *vis a vis* international conservation goals. Protected extents numbers show that 26 marine habitats (7 of which are endangered and 2 are rare ones) meet the Aichi Biodiversity Target 11 of reaching a 10% level of protection by 2020. Nonetheless, another 29 marine habitats (four on shelf and 25 in the deep-sea) fail to meet this target, highlighting the unbalance between coastal and deep-sea protection and the need to extend protection of bathyal and abyssal habitats.

The application of a regulation-based classification of MPAs provides a state-of-the-art and objective way to qualify extent-based numbers, which on their own could bias the perception of how well the ecosystem is protected. We show that nearly the entire MPA network is classified as highly protected whilst highlighting a general shortage of fully-protected areas across the region's EEZ that could more effectively safeguard the Azores marine biodiversity from direct and diffuse pressures. In the current configuration of the MPA network, stronger levels of protection like those endorsed in the "Promise of Sydney" (30% of fully-protected areas) could just be envisaged for infralittoral habitats, and only if the on-shelf MPAs were more forcefully regulated. Results further demonstrate that few existing MPAs include some sort of zoning, contrarily to marine planning recommendations to establish buffer zones around core sites.

These results provide a basis for decision-makers to address conservation shortcomings per marine habitat and demonstrate an approach transposable to other European regions and beyond where similar information is available. The new habitat and MPA maps should facilitate designing a network that meets international extent-based conservation targets as well as ecological coherence criteria. Improving the confidence in some habitat classes require finer surveys that should permit discriminating priority habitats whose occurrence and distribution in the region is currently impossible to gauge.

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