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ORIGINAL PAPER

Evaluating seabed habitat representativeness across a diverse set of marine protected areas on the Mid-Atlantic Ridge

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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, but modelling techniques can be applied to produce predictive distribution maps. A harmonized broad-scale seabed habitat map was recently produced for the archipelagos of 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 set of marine protected areas (MPAs) in the Azores to the variety of benthic marine habitats found in this oceanic region. A more objective assessment of the protection effectively provided to the habitats is obtained by applying a scoring system to the MPAs based on the number of allowed extractive and non-extractive human activities and their potential impact on marine biodiversity and habitats. Results show that Azorean habitats within the MPAs are nearly entirely classified as highly protected. In total, 26 habitats (7 of which are endangered and 2 are rare) have at least 10% of their extent in the Azores EEZ protected by MPAs, but another 29 fail to meet this target (4 on-shelf habitats and 25 deep-sea habitats), highlighting the need to extend current protection of bathyal and abyssal habitats and applying adequate ecological coherence criteria. This approach sets a standard that 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

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Introduction

Marine ecosystem-based management has been endorsed as the most comprehensive and desirable approach to manage human activities in the seas and oceans for at least three 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 decision-making processes is good knowledge on the diversity, extent and distribution of seabed habitats. As a result, cataloguing and 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 harmonised 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 the design of representative marine protected area (MPA) networks, 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., the connectivity (OSPAR 2007). This has seldom been accomplished as many MPAs networks have been put together via a succession of uncoordinated initiatives with no consideration of connectivity between units, and they might rather be referred to as set of MPAs (Roff 2014).

The Azores region is a remote sector of the wider North Atlantic associated to an important Exclusive Economic Zone (EEZ) totalling nearly 1 million km^2 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 regional set of MPAs 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 MPAs are implemented 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 (APs), and (c) small (non legally-binding) fishing closures promoted by local stakeholders.

Ecological knowledge available at the time of MPA creation was limited. 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 MPAs and propose necessary amendments (see Abecasis et al. 2015).

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

In this study, the newest EUSeaMap broad-scale habitat map is used to evaluate the representativeness and level of protection awarded by the Azores set of MPAs 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 MPAs 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 types of information are combined to produce an extent-based analysis of the seabed habitats designated under the current set of MPAs accounting for the level of protection they statutorily afford from the regulations in place.

Material and methods

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 (Fig. 1). The Azores EEZ encloses an area of nearly 1 million km^2. Because of their volcanic origin, the islands and the ca. 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

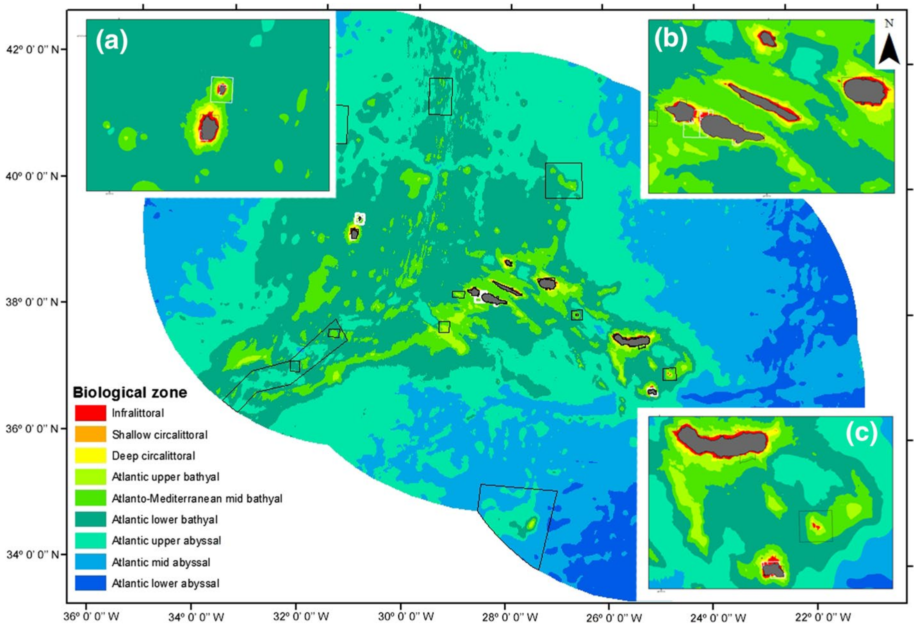


Fig. 1 EMODnet-based biological zonation in the Azores subregion of the Portuguese EEZ as defined by light penetration, wave energy (wave base ratio) and bathymetry. Insets show **a** the western group, **b** the central group, and **c** the eastern group. Rectangles represent current MPAs classified per protection level (white for moderately protected areas, black for highly protected areas, brown for fully protected areas). *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/)

et al. 2013). Shallow areas (< 200 m 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).

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 1 and takes on board recent refinements proposed to the bathyal and abyssal thresholds (see Populus et al. 2017 for details).

Geospatial layers downloaded from the Seabed Habitats EMODnet Portal on 17th October 2017 were used as the source of biological zone data (Table 1) and habitat data (Table 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

Table 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 day^{-1}
Shallow circalittoral	Wave base ratio (= wave length*/depth at seabed)	0.4 mol. phot. m^2 day^{-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	2200 m	3200 m
Atlantic mid abyssal	Seabed depth thresholds	3200 m	4300 m
Atlantic lower abyssal	Seabed depth threshold	> 4300 m	

*3-year mean of percentile 90

Table 2 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	Deep-sea bedrock	Atlantic lower abyssal	Rock or other hard substrata	Low energy
A6.11	Deep-sea bedrock	Atlantic lower bathyal	Rock or other hard substrata	Low energy

Table 2 (continued)

EUNIS code	Habitat EUNIS	Biological zone	Substrate	Energy
A6.11	Deep-sea bedrock	Atlantic mid abyssal	Rock or other hard substrata	Low energy
A6.11	Deep-sea bedrock	Atlantic upper abyssal	Rock or other hard substrata	Low energy
A6.11	Deep-sea bedrock	Atlantic upper bathyal	Rock or other hard substrata	High energy
A6.11	Deep-sea bedrock	Atlantic upper bathyal	Rock or other hard substrata	Moderate energy
A6.11	Deep-sea bedrock	Atlantic upper bathyal	Rock or other hard substrata	Low energy
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

Table 2 (continued)

EUNIS code	Habitat EUNIS	Biological zone	Substrate	Energy
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

NA not applicable

(e.g., Projects MAROV, MARÉ, GEMAS, BIOTOPE, OGAMP, MARMAC). Overall habitat confidence of the EUSeaMap is medium (coastal areas) to low (bathyal and abyssal), although certain layers to create this final map have high confidence (Vasquez et al. 2015; Populus et al. 2017).

Prior to the analysis, the EUSeaMap data layer (EMODnet 2017) was projected to the 'PTRA 08/UTM zone 26 N' 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 down to level 4, if possible. To compare areas classified with different habitat levels (i.e., levels 2–4), we separated them based on their associated biological zone, substrate type and energy level (Table 2). 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®).

Set of MPAs

Five types of legally designated areas were considered as components of the Azores set of MPAs, comprehending coastal and offshore areas. All of them have regulations that limit human activities directly affecting organisms associated with the seafloor and thereby contribute to achieving biodiversity conservation and living resource management goals. They consist of: (1) INPs generally aimed at protecting coastal areas (number of MPAs = 35); and (2) the large 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 and classified according to IUCN categories (Abecasis et al. 2015). 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) 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 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.

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 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 the majority of the Azores EEZ [Council Regulation (EC) No. 1568/2005; DLR No. 29/2010/A, republished in Annex II to DLR No. 30/2012/A]. HRs 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

Table 3 Summary of existing fishing gears for commercial and recreational fisheries, and other activities with corresponding scores in the Azores (adapted from Horta e Costa 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 non-extractive activities	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

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 and critically assessed. For this purpose, a target of including a minimum of 10% of each habitat was used, as it represents the minimum from the 10 to 30% interval recommended in international guidelines for the protection of marine ecoregions or habitats altogether (Convention on Biological Diversity 2010; Laffoley et al. 2008; Wenzel et al. 2016).

Results

Biological zones and EUNIS habitat types

The biological zonation of the Azores EEZ resulting from the EUSeaMap layer is presented in Fig. 1. The EEZ (954.5×10^3 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 4).

A total of 28 unique EUNIS habitat types (from level 2 to 4) 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; Fig. 2; e.g., 6 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, present 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 (Fig. 2). Almost the entire Azores EEZ was classified as deep-sea bed (99.8%, A6; Table 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 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

Table 4 Representativeness of biological zones (italics) and EUNIS habitats of the Azores Economic Exclusive Zone and percentage of the area included in the Azores MPAs 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[dd]/A5.24	130.5	16.0	0	27.3	21.3	48.7 (63.5)
A5.331	1.0	0.1	0	0	0	0 (0)
A5.341	0.2	< 0.1	0	0	0	0 (0)
A5.43[dd]	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[dd]	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)

Table 4 (continued)

Habitat type	(% EEZ) Total area (km^2)	% Habitat per biological zone	% Fully protected	% Highly protected	% Moderately protected	% Total protected (km^2)
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) 41,108.1*		*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	10,052.1	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	22,175.5	53.9	0	2.0	< 0.1	2.1 (457.9)
Atlantic lower bathyal	*(20.4) 194,831.0*		*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	177,122.7	90.9	0	4.6	< 0.1	4.6 (8083.1)
Atlantic upper abyssal	*(27.2) 259,985.2*		*0*	*5.2*	*0*	*5.2 (13,456.7)*

Table 4 (continued)

Habitat type	(% EEZ) Total area (km^2)	% Habitat per biological zone	% Fully protected	% Highly protected	% Moderately protected	% Total protected (km^2)
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	250,982.2	96.5	0	5.3	0	5.3 (13,376.8)
Atlantic mid abyssal	*(32.1) 306,729.4*		*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	11,544.3	3.8	0	< 0.1	0	< 0.1 (< 0.1)
A6.5	292,322.3	95.3	0	2.7	0	2.7 (7803.8)
Atlantic lower abyssal	*(15.1) 143,753.1*		*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	143,388.9	99.7	0	0.1	0	0.1 (199.9)
Total area EEZ	*954,499.7*	*100*	*< 0.1*	*3.6*	*0.1*	*3.6 (34,606.5)*
Shallow habitats	1809.7	0.2	< 0.1	16.3	11.7	28.1 (508.2)
Deep sea habitats	952,690.0	99.8	0	3.5	< 0.1	3.6 (34,098.3)
NI habitat in shallow zones	207.3	11.5	< 0.1	22.3	15.4	37.7 (78.1)

NI non-identified habitat

[*]Threatened/[dd]data deficient habitats listed in EU Red List

[1]Rare habitats

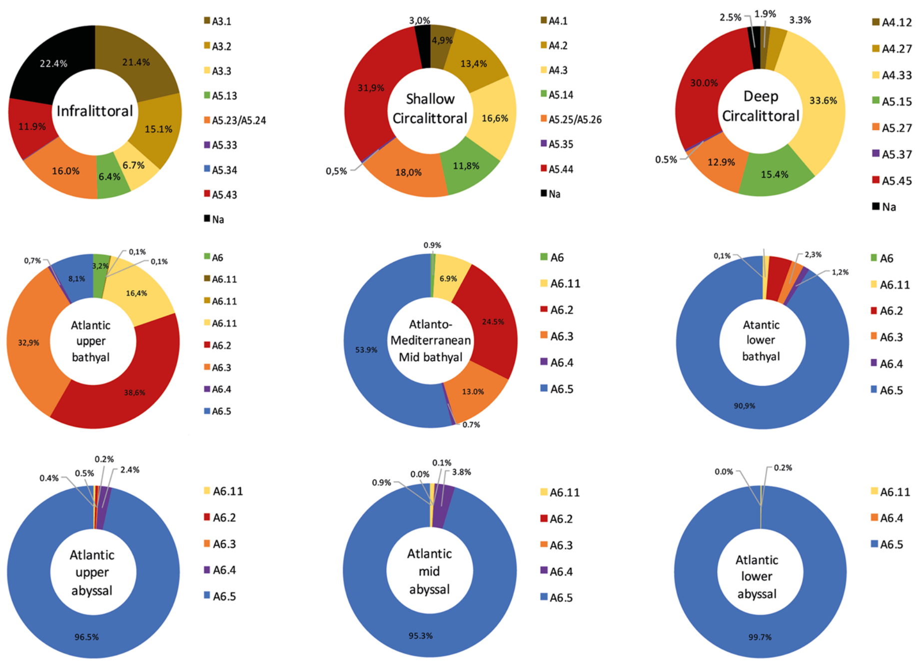


Fig. 2 Representativeness of EUNIS habitats in the different biological zones of the Azores (*NA* non-identified habitats, *threatened habitats listed in EU Red List, [1]rare habitats)

communities on deep low energy circalitoral 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 4).

Nine of the identified EUNIS habitats are listed as threatened on the EU Red List of marine habitats, i.e., 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 km^2 (Table 4). Three other habitats (A4.12, A5.23, A5.43) are data deficient.

Regulation-based classification of MPAs

The application of the different protection typologies resulted in a total of 100 legally designated areas that cover a total of 34,606.5 km^2 or 3.6% of the Azores EEZ (Table S1; Fig. 3). This re-organization contained a final set of 46 MPAs composed of 93 zones. A single MPA encompassed up to 10 zones with distinct protection regime (Table S1) and a maximum of 4 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 S1).

The application of the regulation-based classification system resulted in three types of MPAs ranging from 'fully-protected area' to 'moderately-protected area' (Table S1; Fig. 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

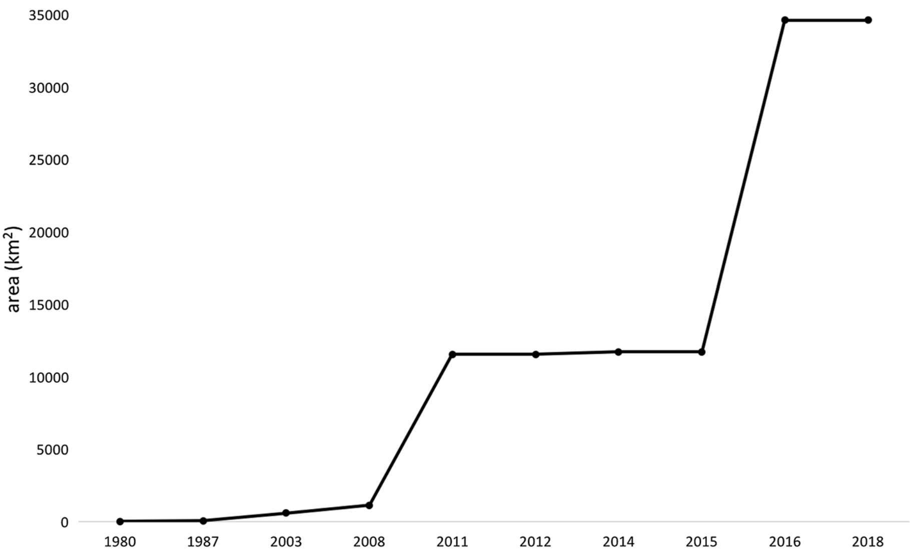


Fig. 3 Temporal evolution of the total protected marine area in the Azores Archipelago; values include all five types of designated MPAs in the region (see text for explanation)

to be fully protected (< 0.01% of the EEZ, Table 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 Azorean MPAs (Table S1).

Biological zone and habitat coverage by the MPAs

The set of MPAs 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 4; Fig. 4). Shallow habitats with no associated seabed data in the MPAs represented 37.7% (Table 4).

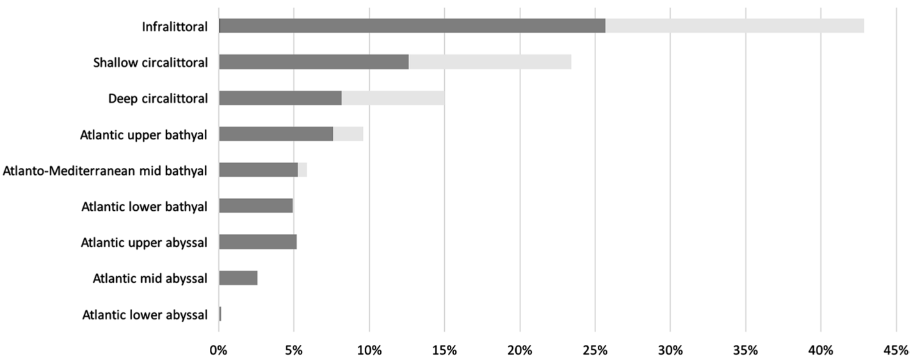
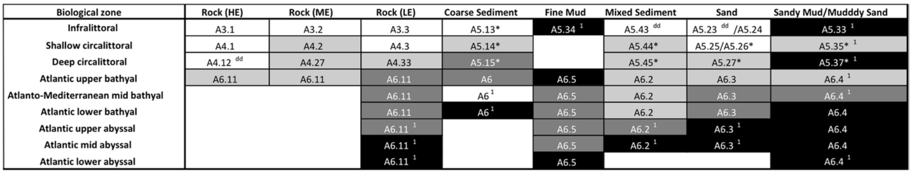


Fig. 4 Representativeness (in %) of each biological zone set of MPAs in the Azores, classified by level of protection. 10 and 30% thresholds were adapted from Aichi Biodiversity Target 11 and Sydney Recommendation, respectively. The colour code represents level of protection: light grey as moderately protected, dark grey as highly protected and black as fully protected. *Note* the only fully protected area covers a mere 0.1% of the infralittoral



Biological zone	Rock (HE)	Rock (ME)	Rock (LE)	Coarse Sediment	Fine Mud	Mixed Sediment	Sand	Sandy Mud/Mudddy Sand
Infralittoral	A3.1	A3.2	A3.3	A5.13*	A5.34 [1]	A5.43 [dd]	A5.23 [dd] /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 [dd]	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]

Fig. 5 Representativeness of each EUNIS habitat per biological zone set of MPAs in the Azores (*threatened habitats/[dd]data deficient habitats listed on 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%

Fully protected areas encompassed a single habitat (infralittoral mixed sediments (A5.43) in a single MPA; Table 4; Table S1). 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 4). On the other hand, some of the identified EUNIS habitat types were either not covered by the set of MPAs (seven habitats, all considered as rare habitats) or nearly absent (< 1%, eight habitats) (Table 4; Fig. 5). Furthermore, just 26 of the 55 habitats meet the defined target and have more than 10% of their total area protected (Fig. 5).

Coverage by the MPAs 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 (Fig. 5). 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%).

Discussion

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 (< 200 m) 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 sonar (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 nine identified habitats listed on the EU Red List of marine habitats as threatened (including endangered and vulnerable for the Azores; Gubbay et al. 2016), 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, such as A1.34, A5.13, A5.14, A5.45, A5.51, and A5.53 (e.g., maerl, seagrass, corals; Tempera et al. 2013) which are all classified as threatened (Gubbay et al. 2016).

Filling these knowledge gaps and producing a cross-over table between classifications and protected habitats should thus be a priority. However, it is important to emphasize that each assessment has its limitations and some important habitats may have not been evaluated due to insufficient data. In the IUCN Red List, for example, 60% of the Atlantic habitats are considered 'data deficient' (including habitats A4.12 or A5.43, which exist in the Azores), and deep-sea habitats (A.6 and respective levels below) are not included at all. This may result in a underrepresentation of sensitive habitats. For example, habitat A4.12 includes several species that are considered vulnerable, fragile, and unlikely to recover if damaged by bottom fishing gear (notably sponges; Malecha et al. 2017).

The Azores MPAs

This study provides an integrated view of the Azorean MPAs 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 can actually 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. Fishing activity, for example, is prohibited in FMAs (except for bait fishing) and APs and first positive signs are observed (i.e., an increase of abundance and biomass of certain fish species; GAMPA 2019, unpublished data).

Different factors explain why most of the areas in the Azores MPAs 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 9 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, 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).

As long as there are no major changes in the current seabed exploitation (including the use of highly impacting fishing gears and seabed mining) and aquaculture regimes, the Azorean MPAs will maintain their Moderately to Fully Protected status under the regulation-based classification. This situation is similar to MPAs in other Portuguese regions (Horta e Costa et al. 2019), where fully protection is residual and the less protected class is moderately protected. This is a relevant level of protection when compared with most other regions in Europe, which would most possibly be considered Unprotected or Poorly Protected under this classification given their authorisation of higher impact of gears. In several European MPAs destructive extractive activities such as trawling are occurring, undermining their conservation purpose (Dureuil et al. 2018). The fact that the Azores has also benefited from historically low levels of habitat destruction reinforces this difference, as many of those European MPAs are set up in already highly impacted areas which arguably still have to recover (Fraschetti et al. 2013; García-Rubies et al. 2013).

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.

Representativeness of biological zones in the MPAs

The fact that the different biological zones are not equally represented in the Azores MPAs 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). In contrast, shallow areas (infralittoral and circalittoral) are better represented in the MPAs both in terms of diversity and proportions either at the biological zone or habitat level (Figs. 4, 5). In fact, shallow biological zones actually reach the study's 10% target (i.e., infralittoral, 42.9%; shallow circalittoral 23.4% and deep circalittoral 15%) (Fig. 4).

This imbalance 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 AMP in 2011 and its revision in 2016 that substantially increased the deep-sea areas affording protection (Fig. 3).

The broad imbalance 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 (4 shallow habitats and 25 deep-sea habitats) (Fig. 5), failing to reach internationally set targets. The lack of protection of the water column in the abyssal and bathyal zones may have negative consequences for pelagic species, however, this is beyond the focus of this study. Although MPA coverage has recently increased in the Azores (23,065 km^2 newly designated in the last 5 years), attaining the 10% target within the EEZ by 2020 requires considerably accelerating these efforts to designate an additional 61,000 km^2. In fact, the Regional Government of the Azores signed a memorandum with various partners to protect 15% in the next years (https://www.azores.gov.pt/Portal/en/novidades/International_Memorandum_of_Understanding_evidences_ambition_and_leadership_of_the_Azores_in_managem.htm).

The Azores region seems to benefit from the interdiction of bottom trawling which protects benthic habitats and species from direct destruction, in comparison to other regions worldwide, including mainland Portugal. Bottom trawling never occurred in the region, so interdiction of those gears is rather a preventive measure.

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 predicted 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 set of MPAs itself is considered, 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 (i.e., endangered and vulnerable habitats with sufficient data in Gubbay et al. 2016) in the MPAs is rather representative, with seven out of the nine Red List habitats receiving over 10% protection. However, data-deficient habitats are not considered (see above) and some rarer habitats are underrepresented in the MPAs. 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 40 m depths. With regards to the deep-sea, until higher levels of confidence concerning substrate distribution are achieved, we recommend that MPA design resorts to habitat complexes (seamounts, depth zone) whilst applying criteria of ecological connectivity between designated areas.

Conclusions

Assessing the protection offered by current MPAs to the large diversity of (broad-scale) Azorean benthic habitats allowed us to assess the accomplishment of those MPAs vis-a-vis international conservation goals. We show that 26 marine habitats (seven of which are endangered and 2 are rare) meet the 10% target while another 29 marine habitats (4 on-shelf and 25 deep-sea) fail to meet this target. This protection gap is thus more relevant for the ensemble of deep-sea habitats. In spite of the historical absence of high-impact gears in the region, Azorean deep-sea habitats (including seamounts) are more exploited by commercial fisheries (Morato et al. 2006; Menezes et al. 2006), and may potentially suffer higher impacts than coastal habitats. These results thus highlight a priority to tackle the current legal imbalance between coastal and deep-sea protection, in particular the need to extend protection to bathyal and abyssal habitats in the Azores.

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 set of MPAs 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 set of MPAs, 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 and connectivity criteria. Improving the confidence in some habitat classes requires finer surveys that should permit discriminating priority habitats whose occurrence and distribution in the region is currently impossible to gauge.

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