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Abstract

Background

Habitat mapping is necessary for the efficient conservation and protection of marine ecosystems. In addition, it is a requirement for EU Member States as stated in the European Union (EU) Habitats Directive ([92/43/EEC](#)), as well as necessary for the achievement and maintenance of 'good environmental status ([GES](#))' of benthic marine habitats in the framework of the EU Marine Strategy Framework Directive ([2008/56/EC](#)).

New information

This study provides baseline information on the marine benthic habitats of Sozopol Bay (Black Sea) and Karpathos and Saria islands (Mediterranean Sea). These two Natura 2000 sites were selected as study sites of the [RECONNECT](#) project, which aimed at creating a transnational cooperative network to confront the environmental threats of ecosystems with a high natural and cultural interest, by the establishment of common practices and a joint regional strategy. The specific objective was to map the marine habitats using a defined *a priori* classification (EUNIS), with the ultimate purpose of supporting government marine spatial planning, management and decision-making processes through the development of a Decision Support System.

Keywords

habitat mapping, marine benthic ecosystems, Karpathos, Saria, Sozopol, *Posidonia oceanica*, *Zostera* spp., EUNIS, Mediterranean Sea, Black Sea

Introduction

Although the term habitat can be defined in a variety of ways (e.g. Bunce et al. 2013), it usually refers to a combination of living forms and abiotic factors (e.g. soil type and climate) occurring together (Ichter et al. 2014). According to the definition from the European Nature Information System (EUNIS) of the European Environment Agency (EEA), a habitat is "a place where plants or animals normally live, characterised primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality, etc.), and secondarily by the species of plants and animals that live there" (Davies et al. 2004). Similarly, marine habitat mapping as defined by the Mapping European Seabed Habitats (MESH) project is "plotting the distribution and extent of habitats to create a map with complete coverage of the seabed showing distinct boundaries separating adjacent habitats" (Davies and Young 2008).

As required by the European Union (EU) Habitats Directive (92/43/EEC), EU Member States need to identify and designate sites for habitats (as listed in Annex I of the directive) to be included in the Natura 2000 network. The same directive requires EU Member States to report on the conservation status of these habitats at six-yearly intervals, which calls for solid knowledge of their geographical distribution. Therefore, it is clear that habitat mapping is a key feature of ecosystem conservation.

Regarding marine biomes, however, the focus over the last few years has been on the establishment of Marine Protected Areas (MPAs), which are the main tool for protection and conservation of the marine realm (Xuereb et al. 2019). Several concepts have been explored for the effective creation of MPAs, with the concept of Cells of Ecosystem Functioning (CEFs) being the most comprehensive one: the three-dimensional spaces where connections of intra- (e.g. life cycles), inter- (e.g. food webs) and extra-specific fluxes (e.g. biogeochemical cycles) are stronger than in adjacent areas (Boero et al. 2019). However, most of the MPAs in Europe, especially in the Mediterranean Sea, have been established for the protection of key species and do not take all the aforementioned connections thoroughly into account. In addition, they are of small size and are considered to be practically unsuccessful due to lack of efficient financial and political support (Barberá et al. 2012).

General description

Purpose: A successful regional habitat mapping program needs to include the following elements (Ehrhold 2007):

- Clear statement of purpose for the mapping project (e.g. well defined goals and objectives).
- Selections of scales for map extents and data resolution appropriate to the stated purpose.
- A universally accepted and broadly applicable hierarchical habitat classification system based on spatially nested physical and biophysical characteristics that control where species live.
- A means for acquiring data at appropriate resolutions and spatial scales for each of the relevant habitat characteristics.
- A means for combining, analyzing and displaying these various geospatial data sets collected in diverse formats, and at different scales and resolutions such that the habitat classification system may be applied.

In accordance with these general guidelines, we identified the necessary steps for the selection of the mapping approach and methods that were applicable to our marine habitat mapping activities:

- Identification of the spatial extent of the mapping exercise
- Determination of the objects to be mapped: substrate types and biological communities, as well as an appropriate system for the classification of these target types
- Determination of the spatial resolution of the substrate mapping and biological communities mapping
- Selection of appropriate methods for geophysical and biological sampling to fulfil these mapping goals with the available resources and time
- Selection of appropriate data analysis tools and methods for habitat suitability modelling

The aim of this study was to provide habitat maps for two Natura 2000 sites, one in Bulgaria and one in Greece, that were used for the creation of a decision support system for the management of the sites as part of the “Interreg Balkan-Mediterranean 2014-2020” project RECONNECT. The most current EU-wide habitat classification systems for habitat classification with a thorough coverage of the unique benthic habitats of the two sites are the [Habitats Directive classification scheme](#), the [2019 EUNIS classification system](#) and the [Marine Strategy Framework Directive \(MSFD\) Broad Habitat Types](#). The EU Habitat Directive habitat types that are recognized in the EU classification schemes have direct application in Natura 2000 area management, and were the focus of our mapping activities.

Sampling methods

Study extent: The target of our mapping activities in Bulgaria was the maritime part of the Natura 2000 site [BG0000146](#) Plazh Gradina – Zlatna ribka (Fig. 1). It has an area of 1033.5 ha, which includes 933.65 ha of habitat 1110 ([Sandbanks slightly covered by seawater all the time](#)), 95.92 ha of habitat 1170 ([Reefs](#)), and 4.5 ha of habitat 1140 ([Mudflats and sandflats not covered by seawater](#)). The main target for the mapping activities in the study area were the benthic biological communities.

The targeted area in Greece was the Protected Area of northern Karpathos and Saria ([GR4210003](#)) (Fig. 2). Karpathos and the smaller island Saria are located in the southeastern Aegean Sea, bordering the Sea of Crete in the east and Rhodes island in southwest. A narrow strip of sea, no deeper than 80 metres, separates the two islands. The Protected Area is considered to be one of the most important in Greece due to the existence of many rare and endemic species of flora and fauna. Its marine part has an area of 5181.74 ha, i.e. about 45% of its total area, which includes habitat 1110 ([Sandbanks slightly covered by seawater all the time](#)), habitat 1120 ([Posidonia beds \(Posidonion oceanicae\)](#)), habitat 1170 ([Reefs](#)), habitat A5.531 ([Cymodocea beds \(Cymodocea nodosa\)](#)) and habitat 8330 ([Submerged or partially submerged sea caves](#)). Karpathos hosts one of the largest populations of the Mediterranean monk seal (*Monachus monachus*), and has been declared one of the 'Important Bird Areas of Europe'.

Sampling description:

For the Natura 2000 site [BG0000146](#):

The geophysical mapping of substrates and bathymetry was carried out by the Centre for Underwater Archaeology-Sozopol (K. Velkovsky, K. Dimitrov). The survey was set up in a 5 x 5 m grid with a resolution of <1 m for the depth within each frame. The actual resolution of depth depends on the limitations of the side scan and multibeam profilers. The bathymetric survey was carried out with a multibeam sonar Teledyne Odom MB1 (512 beams), while bottom substrate texture types and relief were surveyed with a StarFish 450H side scan sonar. Both were mounted on a research vessel (MK 'Hristina', CUA-Sozopol) with a high precision GPS system (RTK DGPS Trimble). The survey vessel performed transects in the study area, parallel to the shoreline and with at least 20% overlap of the scanned area of the bottom between two adjacent transect lines. The survey covered the sea bottom down to 3 m depth, avoiding any shallow areas and obstacles in the zone. The depths and topography of the areas shallower than 3 m were later interpolated based on available data from previous surveys. All data were continuously recorded on-board the vessel using computers with the appropriate software systems.

The sonograms of the scanned area were later used for the creation of a substrate type map of the zone. This mapping was based on previous geological substrate sampling campaigns in the area, carried out by the Institute of Oceanology-BAS (IO-BAS, L. Dimitrov). The substrate texture types were classified and matched to the Folk-16

substrate classification scheme based on data from transects with over 160 point samples. This included several categories of rocky substrates, soft bottom substrates (sand and mud), soft bottom substrates with seagrasses, and artificial substrates (concrete, pipelines, etc.).

The results from the geophysical mapping were ground-truthed with benthic macrofaunal samples, video and still image drop cameras in a sampling resolution sufficiently dense to cover the different sediment types and depth ranges in the study area following the methodology described in Karamfilov et al. 2017. A 250 x 250 m sample grid was established within the study area; at least one sample/photo/video was taken within each of these sampling squares, ensuring a minimum of 1:25000 resolution of the *in situ* biological data. In areas with higher heterogeneity of habitats, where more than one habitat type was expected to be present within each square (e.g. the rocky coastal zone between 0-1 and 10 m), more than one sample and video/still image observations were taken per square.

Data analysis was performed with the following software products: HyPack for bathymetry data, Deep View for the side scan sonar and mosaic data, and Global Mapper for the creation of substrate and overview maps. The resulting data were saved as DEM, XYZ, GeoTIFF (3D format) for the terrain models, and GeoTIFF and georeferenced JPGs for the side scan data and the collected substrate type data.

Georeferenced photos of the benthic communities were analyzed by experienced benthic ecologists, identifying the substrate types, dominant macroalgal and zoobenthic species visible in the photo, and the dominant habitat types, in accordance with the EUNIS 2019 (level 3 and 4) classification system, as well as the Bulgarian national MSFD habitat types and subtypes. Results were imported in ArcMap 10.4 and the spatial distribution of habitat types was further explored there, by determining the depth limit of distribution of habitats and dominant species on the detailed substrate and bathymetry map of the study site.

For the Natura 2000 site [GR4210003](#):

Bottom substrates were surveyed with a DeepVision (DE3468D) portable side scan sonar trawled on the "Saria" vessel, equipped with a high precision GPS system (GPSMAP78, Garmin). The survey vessel performed a number of transects in the study sub-areas, in most cases parallel to the shoreline and with an overlap of the scanned area of the bottom between two adjacent transect lines. All data were continuously recorded onboard the vessel using a computer with the appropriate software systems installed. Additionally, the BlueRobotics, BLUE ROV2 (ver. heavy duty) underwater drone was used for ground truthing of the different habitat types. The sonograms of the scanned areas were used for the creation of substrate type maps of the area. Data analysis was performed with the software products DeepView Pro for the side scan sonar data, and QGIS3.12 for the creation of substrate and overview maps. Data were exported in KML format by DeepView, transformed into shape files, projected in UTM35 and processed in QGIS on a map scale 1:20000. Polygons of the same habitat were merged so each feature within the

shapefile was assigned to one habitat (1110 soft bottom, 1120 *Posidonia*, 1170 Hard substrate, A5.531 Cymodocea beds).

Quality control:

To ensure that the data would display properly, the shapefiles were cleaned by removing any geometry or topology errors. The shape length and area were calculated in metres and square metres respectively, and all habitats were visualized via Geoserver on MedOBIS viewer (available at <https://portal.lifewatchgreece.eu/>, accessible after registration) in WGS84 coordinate system (EPSG:4326). Download in .csv and .KML format is available through the "Save WMS Layer" tool. An OGC standard for geospatial styling (Styled Layer Descriptor (SLD)) was used through Geoserver to create styles for each layer. Open Street Map was used as a basemap, as it is an up-to-date open source map (Figs 3, 4).

The length and total area of each habitat type in each of the Natura 2000 sites are given in Table 1 and Fig. 5.

Data quality assurance procedures included in the [EMODnet Seabed Habitats](#) data submission process were followed during the preparation of the final datasets. The confidence assessment procedure included an evaluation of the quality, spatial coverage and precision of geographical positioning of the used remote sensing techniques and ground-truthing methods, as well as assessments of the quality, accuracy and representativeness of the produced maps of biological communities. The evaluation results are included in the metadata files of the produced shape files.

Geographic coverage

Description:

For the Natura 2000 site [BG0000146](#):

The official name is Plazh Gradina - Zlatna ribka; located in Black Sea, with an area of 12 km², it is a protected area under Directive 92/43/EEC for the conservation of natural habitats and of wild fauna and flora. The site includes the island of St. Ivan and the small island of St. Peter next to it; the whole bay is called Sozopol. The latter is a beautiful coastal town founded in 611 BC. Sampling area: 14,091859.35 m² (14 km², 1409 ha), of which 3.2% *Zostera* spp. meadows. Depth range: 0-30 m.

An official designation order with detailed management plans and restrictions for the area was published by the Bulgarian Ministry of Environment and Water in May 2021. It includes management measures and regulations that were suggested by IBER-BAS as a result of the surveys completed in this study (Bulgarian State Gazette, [Issue 45/28/05/2021](#)).

For the Natura 2000 site [GR4210003](#):

The selected study sites covered Tristomo and Diafani Bay in Karpathos, Palatia in Saria island, and Steno (Diaplous), the narrow area between Saria and Karpathos. The sampling

area stretches between 35.755691 and 35.887419 Longitude; 27.204275 and 27.235387 Latitude.

Diafani is a traditional fishing village, the second port of the island and is located in the northeast of the island. Sampling area: 647,334.95 m² (65 ha), of which 29% *Posidonia*. Depth range: 0-20 m.

Tristomo is an enclosed bay, a natural harbor, separated by the open sea by three openings, located in the northern part of Karpathos. Sampling area: 479,947.20 m² (48 ha), 5.4% *Posidonia*. Depth range: 0-25 m.

Steno (Diaplous) is the channel between the islands of Karpathos and Saria. Sampling area: 1,867,246.19 m² (187 ha), of which 6% *Posidonia*. Depth range: 0-82 m.

Palatia is a bay in Saria island. Sampling area: 53,539.28 m² (5 ha), of which 17% *Posidonia*. Depth range: 0-41m.

Coordinates: 35.2991739963 and 42.5214755477 Longitude; 27.0079103795 and 27.9142824498 Latitude.

Temporal coverage

Data range: 2019-11-09 - 2019-11-17.

Notes: Primary data from the island of Karpathos and Saria were collected in one visit in November 2019 (09/11/2019 - 17/11/2019). Data for the 'Plazh Gradina - Zlatna ribka' site were collected in a series of field studies carried out between June 2018 and October 2019.

Usage licence

Usage licence: Other

IP rights notes: Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0)

Data resources

Data package title: Habitats of Natura2000 Protected Areas BB0000146 and GR4210003

Number of data sets: 2

Data set name: Soft bottom and hard bottom habitats within the BB0000146 'Gradina-Zlatna ribka' SCI area

Download URL: <https://www.seanoe.org/data/00665/77683/>

Column label	Column description
POLYGON	Unique identifier for each polygon
GUI	Globally unique identifier of the habitat map. It consists of a 2-letter country code + 6 digits
ORIG_HAB	The information of the habitat type present in the polygon, based on Eunis Habitat classification system
ORIG_CLASS	Brief description of the habitat classification system
COMP	A description of the habitats within polygon groups
COMP_TYPE	The type of composition for the habitats within the polygon group. "single habitat" - the polygon is not within a group
Area	The shape area in square metres or hectares

Data set name: Habitat maps of the Protected Area of northern Karpathos and Saria (GR4210003) (December 2020)

Character set: UTF-8

Download URL: <https://www.seanoe.org/data/00666/77813/>

Data format: Shapefile

Column label	Column description
POLYGON	Unique identifier for each polygon
GUI	Globally unique identifier of the habitat map. It consists of a 2-letter country code + 6 digits
AnnexI	Official habitat code of Annex I
ORIG_HAB	The information of the habitat type present in the polygon, based on Eunis Habitat classification system
CONFIDENCE	Confidence in presence and extent of habitat
ORIG_CLASS	Brief description of the habitat classification system
COMP_TYPE	The type of composition for the habitats within the polygon group. "single habitat" - the polygon is not within a group

Additional information

The dataset for the Natura 2000 site [BG0000146](#) is also available at:

<http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/0bf67a42-b478-4ac5-b0df-3e5e9aa638df>

The dataset for the Natura 2000 site [GR4210003](#) is also available at:

<http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/metadata/5877d808-3fd7-11eb-b378-0242ac130002>

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Author contributions

[CRedit \(Contributor Roles Taxonomy\)](#) author statement:

Stamatina Nikolopoulou: Conceptualization, Validation, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Dimitar Berov:** Methodology, Data curation, Investigation, Writing – original draft, Writing – review & editing. **Stefania Klajn:** Data curation, Investigation, Writing – original draft, Writing – review & editing. **Ventzislav Karamfilov:** Writing – review & editing, Funding acquisition, Supervision. **Lyubomir I. Dimitrov:** Investigation, Data Curation. **Kiril Velkovsky:** Investigation, Data Curation. **Eva Chatzinikolaou:** Investigation, Writing – review & editing, Funding acquisition. **Giorgos Chatzigeorgiou:** Data curation, Investigation, Writing – review & editing, Funding acquisition. **Christina Pavloudi:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition.

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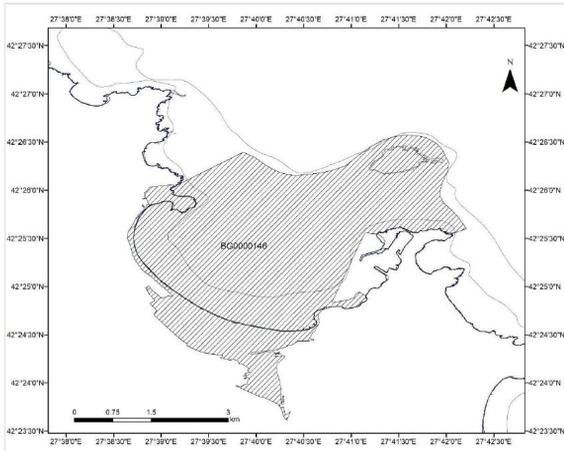


Figure 1.
Spatial extent of the Plazh Gradina – Zlatna ribka Natura 2000 protected area (BG0000146).

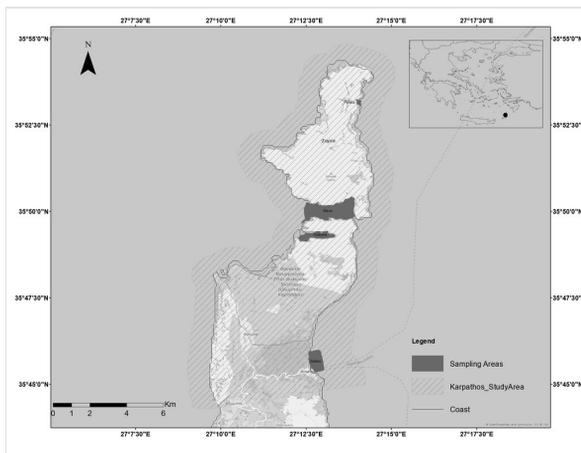


Figure 2.

Spatial extent of the Natura 2000 Protected Area of northern Karpathos and Saria (GR4210003).

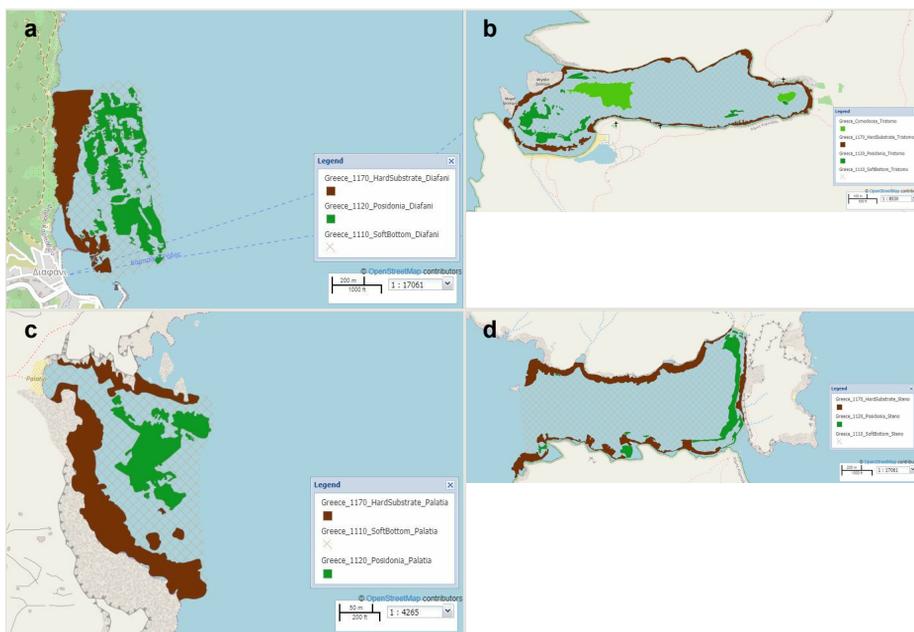


Figure 3.

Habitat maps of the Protected Area of northern Karpathos and Saria (GR4210003).

- a: Map of the Diafani area.
- b: Map of the Tristomo area.
- c: Map of the Palatia area.
- d: Map of the Steno (Diaplous) area.

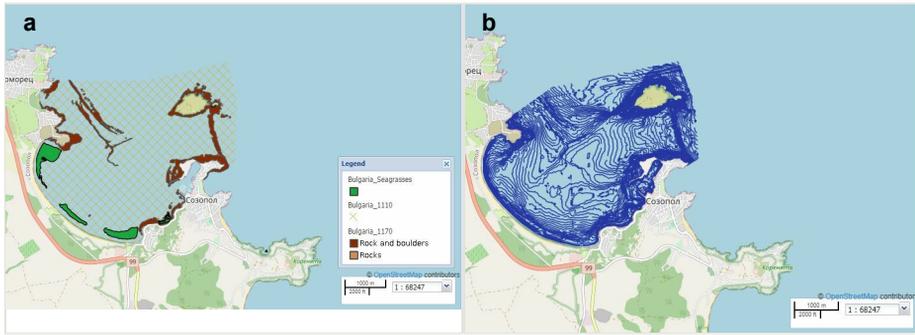


Figure 4.

Habitat maps of the Plazh Gradina – Zlatna ribka protected area (BG0000146).

a: Habitat distribution map of the study area.

b: Bathymetric map of the study area.

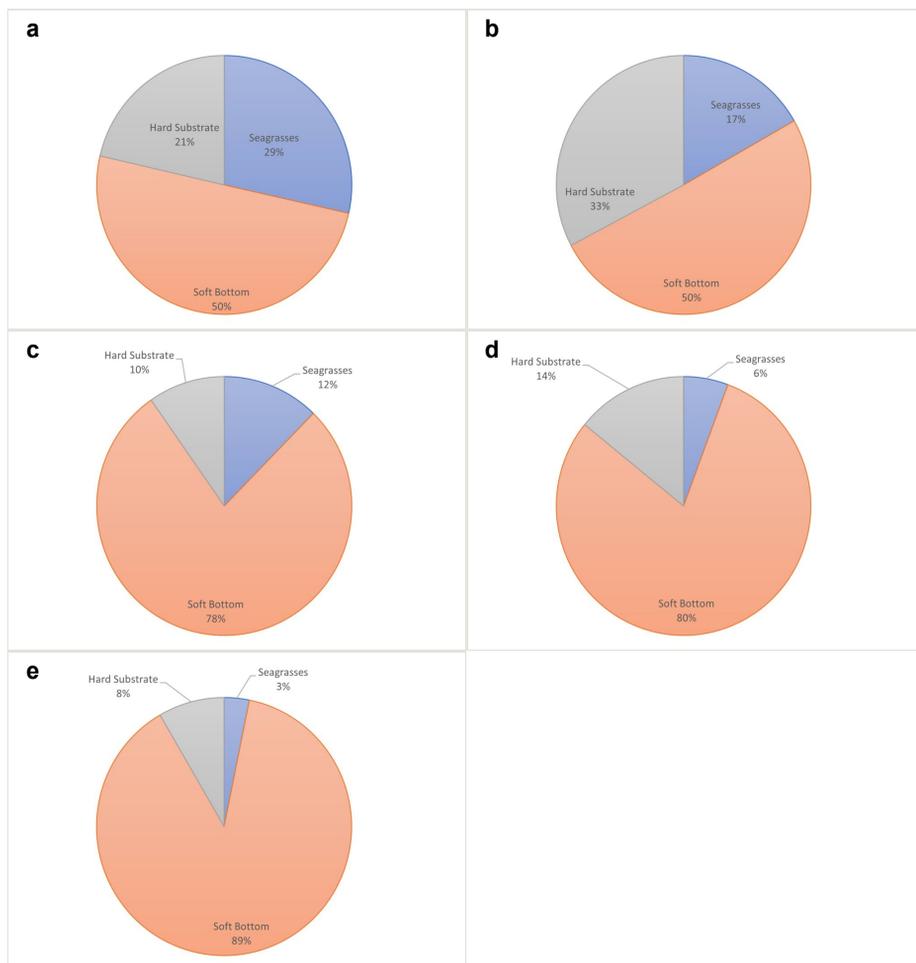


Figure 5.

Shape area (m^2) of the main habitat types of the study sites.

a: Percentages of the shape area of the main habitat types at Diafani.

b: Percentages of the shape area of the main habitat types at Palatia.

c: Percentages of the shape area of the main habitat types at Tristomo.

d: Percentages of the shape area of the main habitat types at Steno (Diaploous).

e: Percentages of the shape area of the main habitat types at Sozopol bay.

Table 1.

The shape area of each habitat type in each Natura 2000 site, as downloaded from the MedOBIS viewer.

		Seagrasses (<i>Posidonia oceanica</i> , <i>Cymodocea nodosa</i> , <i>Zostera</i> spp.)	Soft Bottom	Hard Substrate
		Shape area (m ²)	Shape area (m ²)	Shape area (m ²)
GR4210003	Palatia	8970.28	27041.06	17527.23
	Diafani	184620.62	324222.95	138491.40
	Steno (Diaplous)	105808.65	1496775.74	264661.80
	Tristomo	59073.53	374203.55	46670.13
BG0000146		448757.20	12465103.14	1179832.27