



UNIVERSIDADE DE ÉVORA

Escola de Ciências e Tecnologia

Departamento de Biologia



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Spatial distribution patterns of the sponge community in the Menorca Channel (Balearic Islands), a new Marine Protected Area in the Western Mediterranean

MARIA DEL CARMEN CORBALÁN GARCÍA

Prof. Dr. Josep-Maria Gili (ICM-CSIC)

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Gestão e Conservação dos Recursos Naturais

Dissertação

Évora, 2014



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ABSTRACT

Spatial distribution patterns of the sponge community in the Menorca Channel (Balearic Islands), a new Marine Protected Area in the Western Mediterranean

The INDEMARES project has produced an extensive database obtained from the analyses of 73 video transects recorded with ROV and manned submersible during the cruises INDEMARES 3-4-5-6 and 0811 (years 2010 to 2012) in the Menorca Channel, located between the islands of Mallorca and Menorca.

The information derived from the video transects has been processed and analyzed by the ICM team during the past years. Within the framework of my thesis, data concerning several sponge species was processed focusing in the spatial and bathymetric distribution on the continental shelf and slope.

The distribution pattern of each sponge species was different, however there was a marked preference for the northern deep continental shelf and slope where species reach highest occurrence and abundances.

The results of this study are aimed to complete the scientific knowledge about the different sponge species in order to set the bases toward efficient management and protection of the Menorca Channel ecosystem.

Padrões de distribuição espacial da comunidade de esponjas no Canal de Menorca (Ilhas Baleares), uma nova Área Marinha Protegida no Mediterrâneo Ocidental.

O projeto INDEMARES produziu uma extensa base de dados obtidos a partir das análises de 73 transectos de vídeo gravados com ROV e submersíveis tripulados durante os cruzeiros INDEMARES 3-4-5-6 e 0811 (período de 2010-2012) no Canal de Menorca, localizado entre as ilhas de Mallorca e Menorca.

A informação proveniente dos transectos de vídeo foi processado e analisado pela equipa ICM durante os últimos anos. No âmbito da presente dissertação de mestrado, os dados sobre as várias espécies de esponjas foram processados com enfoque na distribuição espacial e batimétrica na plataforma e talude continental.

O padrão de distribuição de cada espécie de esponja foi diferente, no entanto, houve uma acentuada preferência para a plataforma continental profunda norte e talude onde as espécies ocorrem com maior frequência e abundância.

Os resultados deste estudo são destinadas a completar o conhecimento científico sobre as diferentes espécies de esponjas, a fim de definir as bases para a gestão e proteção eficiente do ecossistema do Canal de Menorca.

INTRODUCTION

The sponges are a very important group; they are abundant and widely distributed in all the oceans, ranging from the poles to the tropics (Joseph 1998, Lo-Bianco et al 1972). They also play an important role in many benthic communities taking part in macro-epibenthic assemblages (Ordines and Massutí 2009, McClintock *et al.* 2005, Ilan *et al* 2004). Besides, some species, due to their tridimensional structure, provide hard substrata (Beaulieu 2001), refuge and habitat to numerous marine invertebrates (Bo M. *et al* 2012, Beazley L. *et al* 2013, and Taylor W. *et al* 2007).

They are great contributors to carbon cycling and nutrients replacement (Renaud 2007, Yahel *et al* 2003, Beazley *et al.* 2013, and Koopmans *et al* 2010). The organic matter produced by the sponges, is introduced to the medium during the life of the animal, either on his own release, as a mucous or reproductive elements, and even during the biodescomposition (Barker 2008, Muricy 1993, Altaba *et al* 1991). Although the sponges are nonselective filter feeders, the volume of water filtering is frequently accompanied by bacteria (Azam *et al* 1983, Ribes *et al* 1999) and the main source of food comes from organic sub-microscopic particles (Lesser and Slattery 2013, Reiswig 1971).

Normally sponges compete for space by the production of metabolites with cytotoxic activity but also cause new spaces and provide substrata for other invertebrates (Altaba *et al* 1991, Barthel 1996, Turon *et al* 2000, Beaulieu 2001, Bell and Barnes 2003) like tanaidaceans, isopods and gastropods whose are epibionts, dwellers or develop a commensalism behaviour respectively (Schiaparelli S. *et al* 2003, Taylor W. *et al* 2007, Amsler et al 2009). Even some studies have described a symbiotic relationship (e. g. Cerrano C. *et al* 2000, Cerrano C *et al* 2007, Taylor W. *et al* 2007). On the other hand, due to the spicules and their toxicity (Hill M. 2005, Uriz *et al* 2003, Green G. 1977, Mc Clintock 1987), sponges couldn't be edible, but nevertheless they are eaten by molluscs, echinoderms and some predatory fishes establishing a specific predator-prey relationship (Barthel 1996, Joseph R. 1998).

Sponges have been the subject in countless studies but the most part of them have been focused in a single species. This studies have target several fields such as genetic, specifically focused on the knowledge of the bacteria communities that produce bioactive metabolites when are sponge-associated (e. g. Silberhorn *et al.* 2007, Hentschel *et al* 2001, Webster *et al* 2001) using molecular techniques of rDNA sequencing in order to find new antibiotics. The situation is similar on chemical studies, those are dedicated to find the biological active metabolites in the benthic community and discover how these substances work, with the aim to find new antibiotics for medicine applications (e. g. Uriz *et al* 1991). Also morphology (e. g. Fine *et al* 2005, Bell and Barnes 2003) and taxonomic studies are still in progress, (e. g. Cardenas *et al* 2013, Ilan *et al* 2004) and the rate of taxon increase with time, finding new specializations and differences between species. (e. g. Barnes and Bell 2002, Bertolino *et al.* 2013, Ilan *et al* 2004, Uriz, Biblioni 1984).

On the other hand, the wide global distribution of sponge communities have boosted up the knowledge about them, however this knowledge is mainly limited to coastal areas (e. g. Rees *et al* 2014, Barnes and Bell 2002, Roberts *et al* 1996, Green 1977). This kind of studies are normally restricted to the use of conventional techniques such as SCUBA or snorkelling. Therefore, in most cases, studies covered small areas (Acosta *et al* 2013, Putschakarn 2007, Weisz 2007) and the benthic communities still being the most unknown.

In the last decades studies about benthic communities have become more complex and have acquired a multispecific character, But most of these studies including epibenthic sleds (e. g. Przeslawski *et al* 2014, Barbera *et al* 2012), Van Veen grab (e. g. Sciberras *et al* 2009, Rosenberg *et al* 2003, Bergen *et al* 2001), bottom trawl (e. g. el Lakhraçh *et al* 2012, Cartes *et al* 2009, Colloca *et al* 2003, Despalatovic *et al* 2009) and other intrusive methods (e. g. Bianchelli *et al* 2010, Gambi 2006, Gremare *et al* 2001).

The remotely operated vehicles (ROVs) have been used in the past years to perform video surveys of the marine benthic communities and populations, covering large areas in a non-intrusive way (e. g. Fossa *et al* 2005, Jones 2009, Whitmire *et al* 2007). The use of ROVs has made possible the study of the population structure in the sponges assemblages and the analysis of the ecological role inside communities (e. g. Bertolino *et al* 2013, Ambroso *et al* 2013, Bo *et al* 2012, Gori *et al* 2011, Barbera *et al* 2012).

The aims of my thesis is to go into the knowledge of the sponge populations in the region of the Minorca Channel, using the extensive database obtained by ROV and manned submersible during the Indemares project, focusing on the patterns of spatial and bathymetric distribution on the continental slope and the continental shelf situated between Menorca and Mallorca islands.

MATERIAL AND METHODS

Study area

The Balearic Islands are located in the western Mediterranean Sea and make a natural limit between the Balearic and the Algerian sub basins (Amores and Sebastià 2014). The Menorca channel connects the islands of Mallorca and Menorca by a continental sub-horizontal shelf, the point where the Balearic Continental shelf reaches its maximum width (Alonso *et al.* 1988). The minimum distance between the two islands from Cala Ratjada to Cap d'Artrutx is 36km. The study area includes the continental shelf and slope with depths ranging from 40 to 360 m (Fig 1).

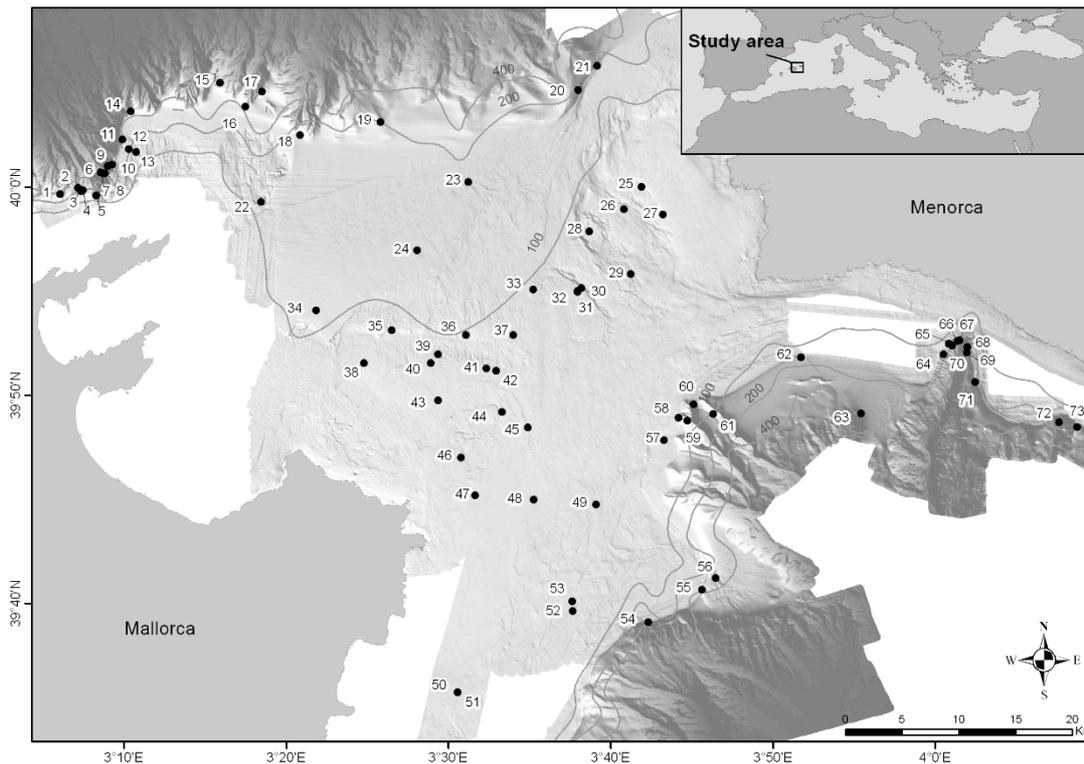


Fig. 1 - Location of the 73 video transects in the study area.

The water balance in the Mediterranean Sea is negative due to high evaporation rates, but this is mainly compensated by the entrance of water from the Atlantic (Hofrichter R. 2005). The meeting of these two water masses (Mediterranean and Atlantic) together with the baroclinic instability and the influence of bottom topography cause currents and meanders (Velez and Belchi *et al.* 2001, Balbín *et al.* 2014, Garcia *et al.* 2005).

Denser Mediterranean waters are distributed over the northern region of the Balearic archipelago while the lighter Atlantic waters are located in the south, forming meanders from the east of Ibiza to the south-east of Menorca (García *et al.* 2005). Furthermore, the presence of eddies directly influences altimetry data, varying the speed, temperature and salinity of the water column (Amores *et al.* 2013). Atlantic water is transported by the Northern current that flows southward along the continental slope from the Gulf of Lions toward Balearic Channels. When the Northern current reaches the channels it splits into two different branches (Amores and Sebastià 2014). One of this branches flows toward the Algerian sub-basin, but the other is the most influential on the Balearic continental shelf and it's called the Balearic Current (Amores *et al.* 2013, Balbín *et al.* 2013).

Due to a very high mesoscale activity, two main western Mediterranean sub-basins can be found: the Balearic and the Algerian (Alemany *et al.* 2006). The distribution of the geopotential anomaly through the Algerian basin implies the presence of two anticyclonic structures first at 38.5 N, 2.5 ° E and second at 39.5 N, 4 ° E. These constitute isolated gyres in addition to showing an intense re-circulation, especially in the anticyclonic gyre south of Menorca, which can still be seen at 100 m depth (Garcia *et al.* 2005). The formation of these isolated gyres is preceded by an intense eastward current (40 cm/s at 20 m) that runs from North to South of Menorca Ibiza (Garcia *et al.* 2005, Balbín *et al.* 2012) (Fig 2).

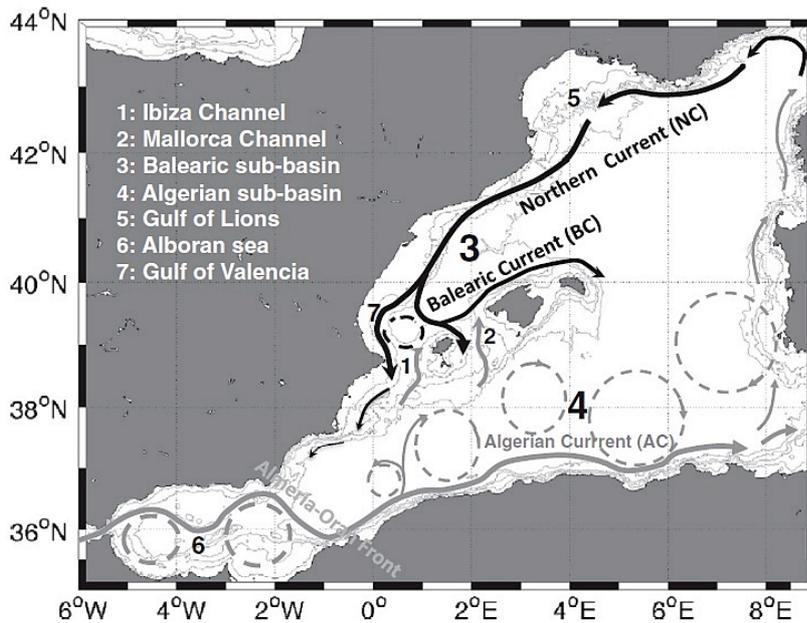


Fig. 2 – Currents describing the regional circulation on the Balearic Islands. The Northern and Balearic Currents are indicated by dark grey arrows and Algerian gyres are indicated by light grey arrows. The isobaths (100 m, 500 m, 1000 m, and 2000 m) are represented as thin lines of light grey (Balbin *et al.*, 2014).

The waters from Menorca Channel are naturally oligotrophic. Low rainfall and the absence of rivers determine a lack of nutrients (Estrada 1996). The channel morphology is characterized as plain except in Menorca area where the undulating shape is generally irregular, the background is regular and the hydrodynamic regime is intense (Alonso *et al.* 1988). The lack of sediment supply from rivers reduces the presence of muddy sediments in the sea, so the muddy bottoms of the Balearic area are only from a biogenic origin (Canals and Ballesteros 1997). The sediment is composed by a sequence of alternating sand mixed with gravel from encrusting algae (Alonso *et al.* 1988). Harder bottom dominate from 40 up to 90 m depth, characterized by maërl and coralligenous rocks (Canals and Ballesteros 1997).

Menorca Channel is one of the ten Spanish high priority areas proposed as possible MPA (Protect Marine Area) because previous studies have described several important habitats, such as *Posidonia oceanica* meadows and coralligenous reefs, and endangered species such as the calcarius Corallinacea algae *Lithothamnion coralloides* and *Phimatolithon calcareum*, and the brown algae *Laminaria rodriguezii* (Barberá *et al.* 2012). One of the most important factors generating heterogeneity in the seafloor landscape over muddy bottoms of continental margins is the occurrence of fields (or meadows) of sessile colonial organisms such as cnidarians, Hexactinellid sponges and deep- water gorgonian corals (Cartes *et al.* 2013).

Video recording

A total of 73 video transects were recorded in the Menorca Channel during five surveys performed between September 2010 and July 2012, all of them as part of the LIFE+ INDEMARES project (Table 1). Video transects were recorded using a Remotely Operated vehicle (ROV) and the manned submersible JAGO, both equipped with high definition cameras, depth sensors, compasses and two parallel laser beams that gave scale to the images. All videos were performed at depths ranging from 52 to 347 meters following the same protocol to minimize the differences between them. The ROV moved over the seabed at an average speed of 0.4-0.5 knots.

Table 1 – Information concerning Indemares campaigns from 2010 to 2012: Period, number of transects, meters, number of sampling units and depth range.

Survei	Period	Number of transects	meters (m)	Number of sampling units	Depth range
Indemares 3	September 2010	9	7011	1052	75-347
Indemares 4	April 2011	11	12427	1866	67-346
Indemares 0811	August 2011	27	14592	2191	52-102
Indemares 5	November 2011	2	1172	176	73-190
Indemares 6	June-July 2012	24	22668	3337	95-270
TOTAL		73	57870	8622	

Video analysis

The videos were digitized and transferred to a hard disk, using the software Apple Final Cut Pro 7. Useless sequences from the video transects were ruled in order to avoid an overestimation of the total length of each transect. The sequences where species were not visible were considered “useless sequences”. This could be due to poor quality of the images or because of the distance from the bottom. The erratic movements of the ROV or the sections in which the apparatus was stopped during the sample collection were removed too, leaving only recordings where colonies were clearly visible and perpendicular to the camera.

With the useful information gathered from the video transects and sponge samples taken during surveys to taxonomic experts, it was possible to identify and classified the sponges present in each transect to genus or species level.

The spatial location was determined by allocating to each organism the time code generated by the program. The spatial code was converted to GPS position using the speed of the ROV, estimated from distance covered and time of immersion. Environmental factors such as depth, substrate and slope were analysed. Four categories of seabed substrate were differentiated: sand to gravel, cobbles and pebbles (coral rubble was include into this category), maërl (species of coralline algae growing loosely in beds of fragmented nodules) and rocks. At the same time, the slope was classified into three categories: horizontal (0-30°), sloping (30-60°) and vertical (60-90°).

Data analysis

After removing the useless sections of video, each video transect was divided into sampling units of 0,3 x 0,66m (2m²). Environmental descriptors (depth, substrate and slope) were assigned to each sampling unit. Then, the density of each species was obtained by counting the number of individuals in each sample unit.

The geographical position of each sampling unit was obtained using the data gathered during each dive by a transponder placed in the ROV, that gave accurate data of latitude and longitude coordinates. The spatial distribution of each species over the continental shelf and slope was obtained using the software ESRI Arc Map 9.3 software. Densities calculated for each sampling unit were displayed in a geographically referenced map in three density distribution classes using the Natural Breaks Classification, which uses the algorithm Jenks Optimization to group values within a class, resulting in classes of similar values separated by breakpoints. This method requires data that is not evenly distributed and not heavily skewed towards one end of the distribution (de Smith *et al.* 2007). The densities per sampling unit were represented using the reference coordinate system WGS84 – UTM31.

The bathymetrical distribution of each species was obtained using the abundance data of each sampling unit over 20 m depth intervals, ranging from 40 to 360 m. In order to get a better representation of the data, species abundance was represented using box plots, alongside with the number of sampling units found at each depth with a different type of substrate.

RESULTS

A total of 17 species of sponges inside Demospongiae class were identified between the continental shelf and slope (fig. 3). *Axinella sp.*, *Chondrosia reniformis*, *Haliclona mediterranea* and *Haliclona sp. 1* were present mainly in shallow continental shelf (< 100 m) except for *Axinella sp.*, which was present in both areas, the rest of species: *Aaptos aaptos*, *Cf. Dyctionella alonsoi*, *Haliclona elegans*, *Haliclona magna*, *Hamacantha falcula*, *Hamacantha sp. 2*, *Hexadella cf. dedritifera*, *Pachastrella monilifera*, *Phakellia robusta*, *Poecillastra compressa*, *Haliclona sp. 2*, *Haliclona fimbriata* and *Thenea muricata* were recorded in the deep continental shelf (> 100 m) and the continental slope (fig. 2). Sponges were recorded in 39,7 % of the total number of 8221 sampling units, and a total of 14.175 individuals were observed along all transects.

Occupancy and abundance

Haliclona sp.2 and *Haliclona elegans* were the most abundant species also in the study area, representing the 38,47% and 17,63% of the total number of observed individuals. Occurring in 7,27% and 3,38% of the sampling units and showing a maximum density of 23 ind/m² and 47 ind/m². *Axinella sp.* and *Haliclona mediterranea* were the most abundant species in the continental shelf, representing 7,7% and 7,3% of the total number of observed individuals. Occurring in 4,72% and 2,04% of the sampling units and showing a maximum density of 16,5 ind/m² and 23,5 ind/m². *Cf. Dyctionella alonsoi* was also one of the most abundant species in the continental self, representing 7,21% of the total number of observed individuals and occurring in the 4,72% of the sampling units but in contrast with the other abundant species, *Cf. Dictionella alonsoi* showing a maximum density of 6 ind/m². This succeed comes because their distribution was wide and homogeneous whereas other abundant species had a patchy distribution. The opposite happens with *Aaptos aaptos* in the sense that it was not the most abundant specie but their presence was highly localized reaching to 14 ind/m². Regarding *Hamacantha falcula*, *Hamacantha sp. 2*, *Hexadella cf. Dedritifera*, *Phakellia robusta*, *Poecillastra compressa*, *Haliclona fimbriata* and *Thenea muricata*, representing values ranging from 1,44 to 2,89% of the total number of observed individuals, their occurrence were from 1,26 to 3,75% of the sampling units and showing a maximum density between 1,5 to 2,5 ind/m². The rest of the species: *Chondrosia reniformis*, *Haliclona magna*, *Haliclona sp. 1* and *Pachastrella monilifera*, representing less than 1% of the total number of observed individuals and sampling units and showing 1,5 to 2,5 ind/m² (table 2).

Table 2 – Sponges presence and spatial distribution in the study area. Occupancy (frequency of occurrence in the set of sampling units); abundance (number of individuals) and maximum density of each specie.

Species	Sampling unit with sp.	(%)	Number of individuals	(%)	Max. density (ind/m ²)
<i>Aaptos aaptos</i>	139	1,69	383	2,7	14
<i>Axinella sp.</i>	388	4,72	1096	7,73	16,5
<i>Cf. Dyctionella alonsoi</i>	388	4,72	1022	7,21	6
<i>Chondrosia reniformis</i>	26	0,32	34	0,24	1,5
<i>Haliclona elegans</i>	278	3,38	2499	17,63	47
<i>Haliclona magna</i>	21	0,25	30	0,21	1,5
<i>Haliclona mediterranea</i>	168	2,04	1043	7,36	23,5
<i>Haliclona sp.1</i>	59	0,72	83	0,59	1,5
<i>Hamacantha falcula</i>	202	2,46	532	3,75	8
<i>Hamacantha sp.2</i>	141	1,71	332	2,34	5,5
<i>Hexadella cf. dedritifera</i>	154	1,87	364	2,57	9,5
<i>Pachastrella monilifera</i>	61	0,74	72	0,51	2,5
<i>Phakellia robusta</i>	123	1,49	179	1,26	2
<i>Poecillastra compressa</i>	238	2,89	342	2,41	4,5
<i>Haliclona sp.2</i>	598	7,27	5453	38,47	23
<i>Haliclona fimbriata</i>	118	1,44	217	1,53	4
<i>Thenea muricata</i>	161	1,96	494	3,48	4,5

Spatial and bathymetrical distribution

The northern slope and deep continental shelf presented a higher sponge species diversity when compared with the shallow continental shelf and the southern deep continental shelf and slope. Generally in the northern slope sponge presence was higher and more widely distributed, but in some cases frequency of occurrence and densities were similar in both areas or were higher in one of them, normally densities and abundances were higher in the northern slope than in the southern slope.

Hamacantha falcula was the only specie present throughout the entire bathymetrical range of the continental slope, at depths between 100m and 360m. This specie showed similar densities and frequency of occurrence in the north than in the south. Secondly Cf. *Dyctionella alonsoi* was widely distributed in the bathymetrical range of continental slope, ranged in depths from 90 to 280m and is frequent and abundant in both areas; north and south of Menorca channel.

Haliclona sp. 2, *Poecillastra compressa* and *Pachastrella monilifera* were distributed at depths between 80 and 260m approximately and were present in the North and South of the study area. The bathymetrical distribution of *Thenea muricata*, also present in the continental slope, ranging from 100 to 280m, but was mainly concentrated at depths from 120 to 160m, where the specie showed the highest density and frequency of occurrence. Equally *Aaptos aaptos* and *Hexadella cf. dedritifera* were present at depths from 80 to 200m and 80 to 260m respectively, but the species displayed maximum density values between 100 and 140m. *Axinella sp.* was present in the continental shelf but also in the shallow continental slope at depths between 40 to 280m showing the highest densities at depths from 40 to 160m. *Chondrosia reniformis* and *Haliclona mediterranea*, were present in the continental shelf, and both were frequent at the same bathymetrical range at depths between 40 and 100m. But *Haliclona mediterranea* showed the highest density and frequency of occurrence (fig. 3).

The spatial distribution of *Cf. Dyctionella alonsoi*, *Hamacantha falcula*, *Hexadella cf. dedritifera*, *Pachastrella monilifera*, *Phakellia robusta*, *Poecillastra compressa*, *Haliclona sp. 2*, and *Haliclona fimbriata* showed a preference into two specific areas, one around the North West and another in the South East of the study area, where they displayed the highest densities. *Aaptos aaptos* is present in both areas too, but is the only specie that shows their higher densities in the southern area of Menorca channel. The spatial distribution of *Haliclona elegans*, *Haliclona magna* and *Hamacantha sp. 2*, appeared to be restricted to this North Western area. On the other hand *Thenea muricata* was mainly found in a small area located in the deep continental shelf on the northern site of the study area. Finally *Haliclona sp.1*, *Axinella sp.*, *Chondrosia reniformis* and *Haliclona mediterranea*, were more frequent and showed a distribution close to continental shelf, in the shallow continental shelf (<100 m) (fig. 5.A, 5.B, 5.C).

DISCUSSION

Although the explored bathymetric range was the same in the northern and southern sites of the study area obvious differences concerning the abundance and specific composition can be appreciated. Higher abundances were observed in the northern side of the study area. This could be attributed to a range of environmental factors such as the availability of appropriate substrate (rock, maërl), slope, etc.

Apart from that, the variation in the hydrodynamic regime of each specific zone could be the best explanation to clarify differences between species distributions in each area (Alemany 2006, Balbin 2012). The hydrodynamic regime has a paramount role in the food supply to benthic communities). The Balearic Islands act as a natural boundary between Balearic and Algerian sub-basins, the northern side of the study area is emplaced within the Balearic basin while the southern study area is nestled in the north of the Algerian sub-basin. The northern slope and northern deep continental shelf are mainly influenced by the Balearic current (Pinot 1995, Balbin *et al.* 2012) and the associated front (Amores and Sebastià 2014). This front is associated with the slope of the archipelago (Pinot *et al.* 1995) being distributed from the surface to 200 meters (Ruiz *et al.* 2009) or 400 meters (Balbin *et al.* 2012). On the other hand the southern insular slope is influenced by the intermittent arrival of detached mesoscale structures from the Algerian current and / or the associated instability of the Almeria and Oran front (Millot 1999, Rodriguez *et al.* 2013).

Several authors suggest that fronts may act as a link between the deep sea and the photic zone (Vélez-Belchí and Tintoré 2001) increasing the productivity (Longhurst 1998). According Mauna *et al.* (2011) fronts have a strong influence on the structure and diversity of benthic communities. The mesoscale processes governing the southern subzone are intermittent, therefore, they can cause occasional increases in productivity (Estrada *et al.* 1999) so they are less influential for benthic communities of southern Menorca Channel.

Considering this facts, greater abundances and sponge diversity observed in the northern side of the study area, could be explained due to the constant food supply provided by the Balearic current / front. On the other hand lower abundances observed in the southern side of the study area could be related to lower food availability as a consequence of the inconstant hidrodinamical conditions.

This partnership between filtering benthic populations and the presence of current and / or fronts has been previously described by studies (e. g. Thiem *et al.* 2006, Gori *et al.* 2011, Ambrose *et al.* 2013, Huff *et al.* 2013).

It is also important to highlight the presence of the Son Bou canyon (39.8° N, 4° E) located in the southern part of the study area. In this particular area higher densities and greater species diversity have been observed when compared to other southern areas. This could be related with the fact that submarine canyons generally operate as suspended particles (Granata *et al.* 1999) and organic matter sinks originated in shallow areas (Poydenot 1993, Gerino *et al.* 1994, Okey 1997, Vetter and Dayton 1998, Harrold *et al.* 1998). Consequently canyons have been described as areas where organic enrichment takes place and where benthic biomass increases (Vetter and Dayton 1998, De Leo *et al.* 2013). Also near bottom intense currents (Shepard *et al.* 1974) and increase in secondary productivity (Vetter *et al.* 2010) have also been described, both factors can potentially benefit filter feeders. Therefore, the densities and species diversity observed in the head of the Son Bou canyon is probably related to a higher food availability compared with adjacent areas.

Generally all the slope species were present in the south, close to Son Bou canyon. But only *Aaptos aaptos* shows their higher densities in this point.

On the other hand, it can be argued that the presence of sponges at different depths responds to the availability and type of substrate. In this study were differentiated four categories of seabed substrate:

sand to gravel, cobbles and pebbles (coral rubble was include into this category), maërl (species of coralline algae growing loosely in beds of fragmented nodules) and rocks. (Fig. 6)

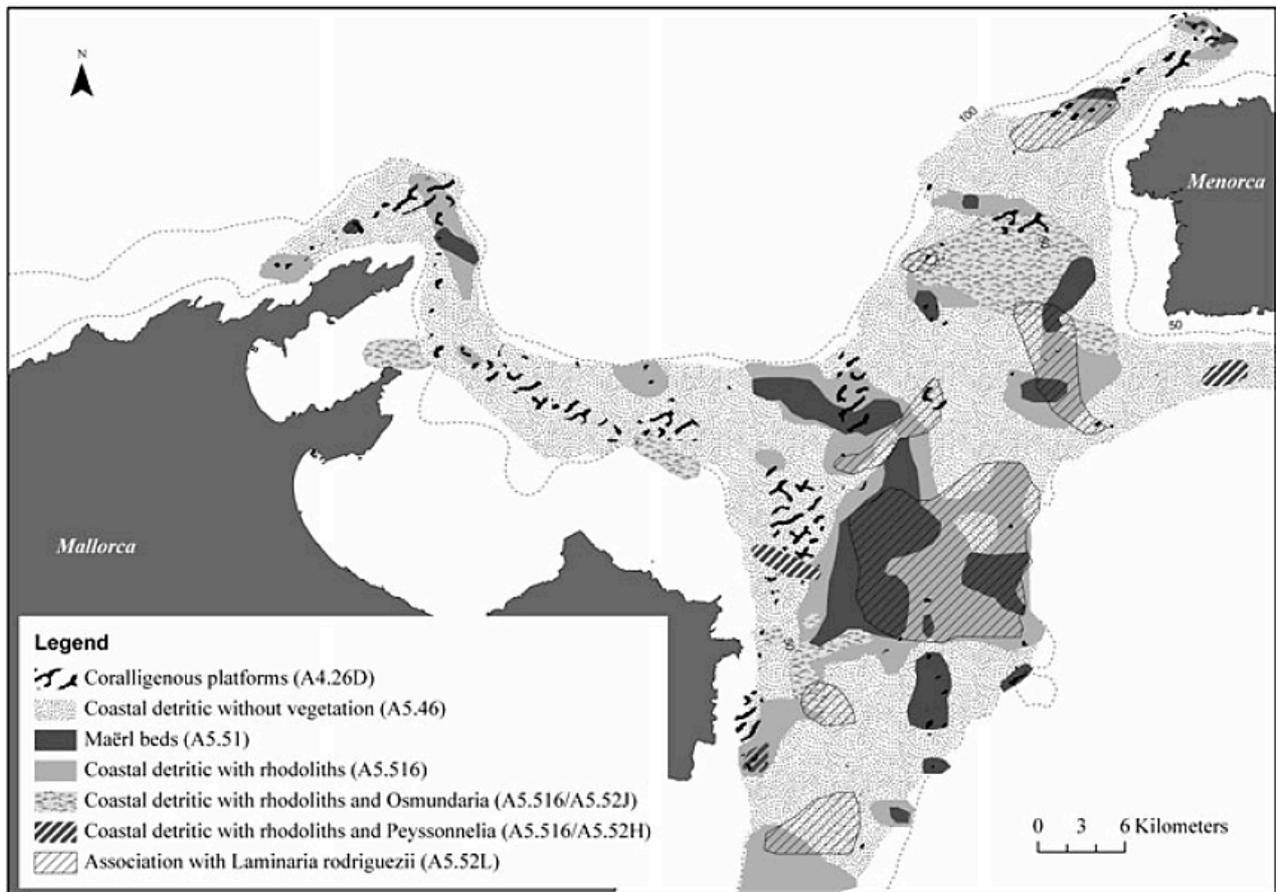


Fig. 6 – Types of seabed substrate in the shallow continental shelf (<100 m) of the Menorca Channel based on side-scan sonar interpretations and visual information (camera and ROV). The habitat code according to the EUNIS classification is specified between brackets (Barbera *et al* 2012).

Haliclona mediterranea, *Chondrosia reniformis* and *Axinella sp.* are the species with the shallowest bathymetrical upper limit, starting at 40 meters and ending at 100 meters. It must be taken into account that the bathymetrical range of the central area of the Menorca Channel varies between 40 and 90 meters and it is mainly dominated by maërl and rhodoliths and in less extension by coralligenous rock beds (Barberá *et al.* 2012). This three species density and frequency of occurrence could be related with the fact that maërl and rhodoliths are the predominant substrates and not by the food availability.

It must be taken into account that most available information concerning this species is mainly taxonomical and very few ecological information is available.

Currently *Thenia muricata* is considered a deep sea species (Gebruk *et al.*, 2010, Boury *et al* 1994, Uriz 1981) however recently this species has been observed at shallow depths (Ramon *et al.* 2014). This results are in accordance with what we have observed in this study.

Poecillastra compressa show a very wide geographic range and high abundance. In recent literature is mainly related in deep sea between 0 to 1740 m on all types of substrates (Uriz 1981, Boury *et al.*, 1994) but the results of this study are in accordance with those reported by Bo *et al.* (2011) were sponges extend between 120 and 180m depth.

Pachastrella monilifera is frequent between 380-500m and is widely distributed over the entire explored sea ground sharing a great morphological and dimensional plasticity, which allow them to grow in a wide variety of different environments and on several types of substrate (Bo *et al.* 2011).

Several studies indicate that *Chondrosia reniformis* is normally common and cosmopolitan marine demosponge (Lazoski *et al.*, 2001, Fassima *et al.* 2014) and is present in the litoral zone and has a wide distribution (Bertolino *et al.* 2013). Including rocky cliffs or caves at a depth range of 1–50m (Fasinini *et al.* 2012, Camillo *et al.* 2012). This would mean that in this study we have encountered this species deep bathymetrical limit. It also appears that the key to its propagation according to Camilo *et al.* (2012) is because their asexual reproduction via drop-like propagules (creeping) and detachment of the propagules precede the fragmentation of the individuals.

Haliclona fimbriata was recently identified and described first time by Bertolino *et al.* (2013) therefore there is little information about its ecology. It is described like a shoal dominant sponge species, adapted to silted environments and is very common on the horizontal and sub vertical substrates of deep hard coralligenous. It was observed together with *Haliclona magna* between 60 and 150m deep along Sardinian coast. These data come in line with the results of this study. Concerning *Haliclona magna* there are several environmental adaptations and survival strategies in relation to environmental conditions that could explain their wide distribution, in terms of morphology: encrusting on beating areas or massive at deeper levels where biotopes are more stable (Uriz *et al.* 1981).

Other studies like Nakisah (2012) relate *Aaptos aaptos* to shallower depths (8-15m) and *Phakellia robusta* with bathymetric ranges from 20 to 210m in the Mediterranean and 85-920m in the Atlantic (Boury *et al.* 1994). For the rest of species the ecological information is very scarce or the only available information is taxonomical therefore no comparison with other studies could be done. For those undescribed species this is the first approach to explain some of their ecological aspects.

CONCLUSIONS

The data analysed in this study demonstrate a strong presence and occurrence of sponges through the study area. Generally the distribution patterns of the species revealed a preference for two specific areas: the north western continental slope and the Son Bou canyon located in the south eastern slope.

Related to hydrodynamic regime, moreover, the specific species of the continental shelf were widely distributed in its bathymetric range, from shallower to deeper areas extending over the shallower slope as is the case of *Axinela sp.* on the other hand, only one species, *Aaptos aaptos* showed their highest densities in the southeast of the study area also being frequent in the northern area. The rest of the species are notoriously present in North and South of the study area with differences in densities, abundances and bathymetrical range.

The reasons that explain this distribution could be attributed to the hydrodynamic regime, the availability of food, substrate type and even depth as shown in other studies.

This could be an indication that the spatial and bathymetric distribution of sponges respond to their physiological needs and each area determines the presence of species at different depths according to the environmental suitability and stability.

Despite the scarcity of information regarding the species observed in this study, some comparisons have been achieved. Species bathymetrical distribution is in accordance with other Mediterranean areas. For those undescribed species this is a first ecological approach so it is important to keep investigating them to explore the ecological role and establishing a possible connectivity between deep sublittoral species and shallow populations.

To carry it out, it is appropriate to continue using non-invasive techniques such as the use of ROVs and manned submersibles that cover large areas and generate a large amount of data while maintaining the integrity of benthic communities.

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ANEX
Figures and Tables

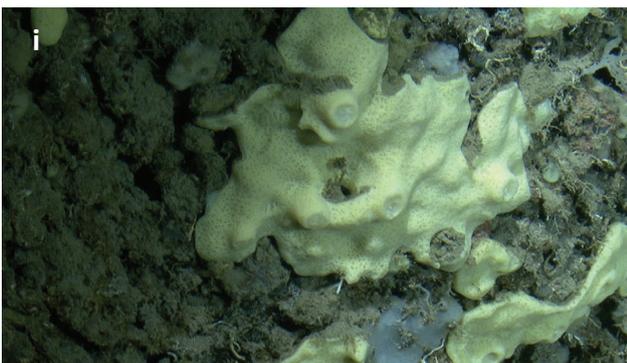
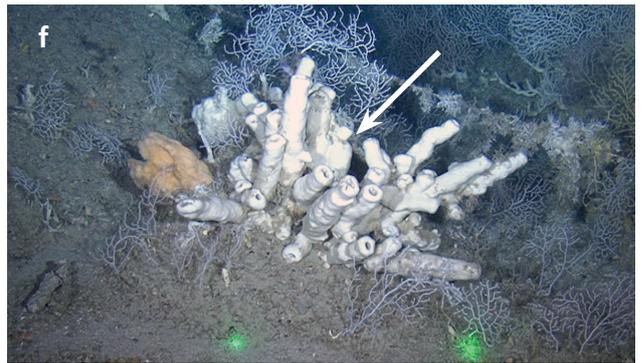
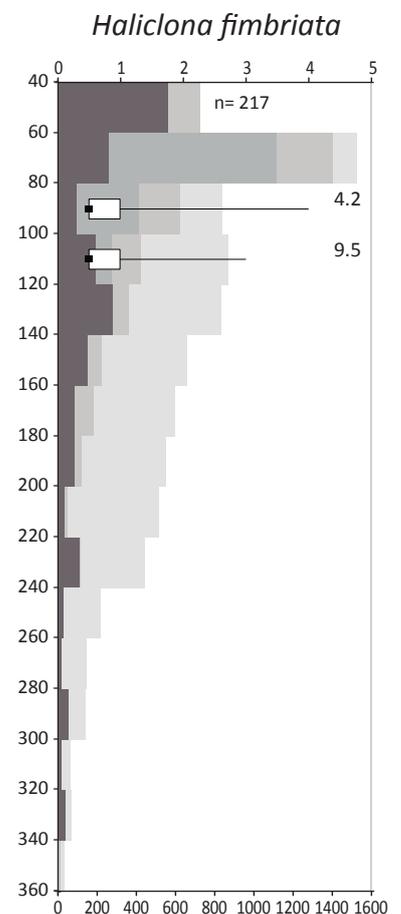
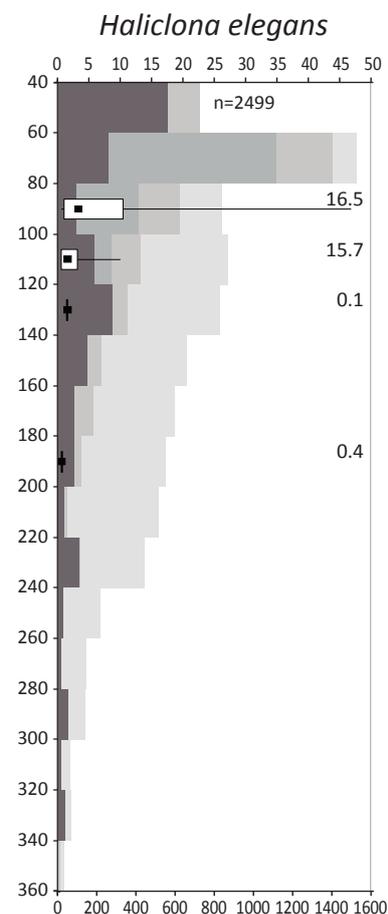
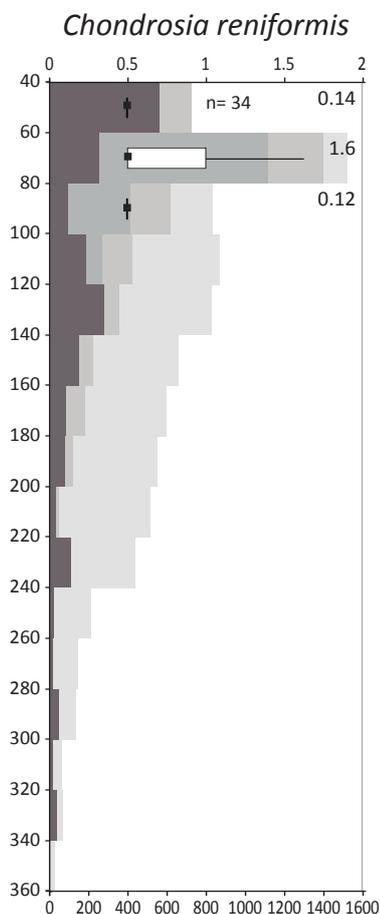
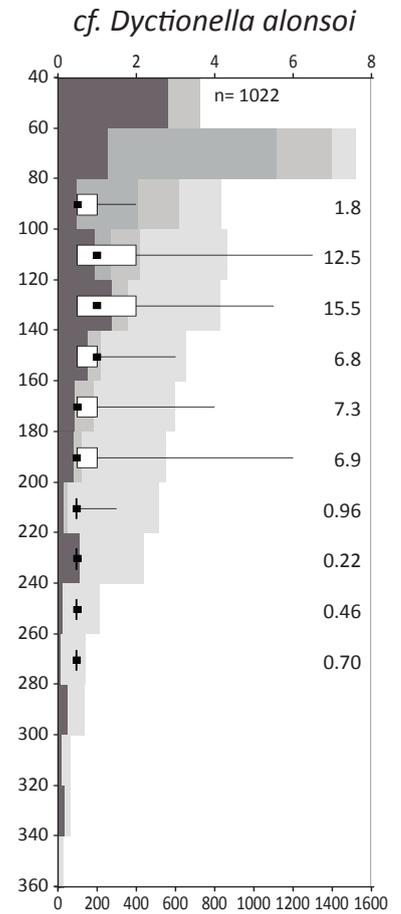
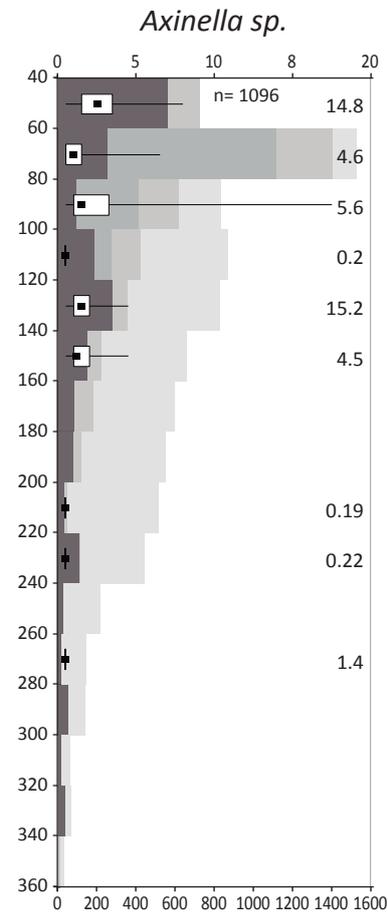
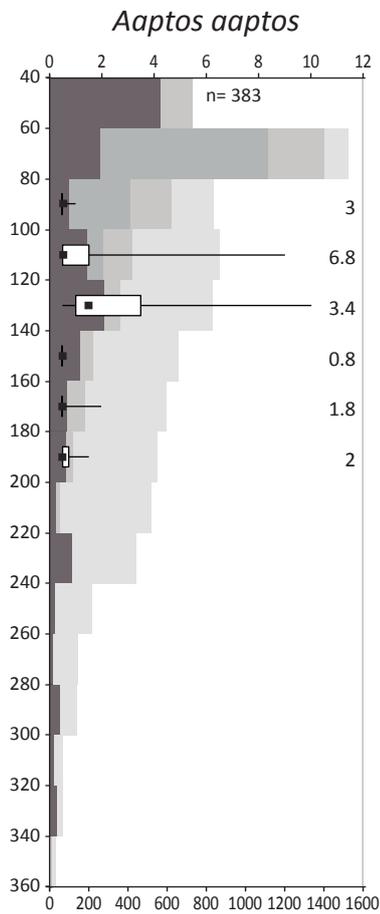




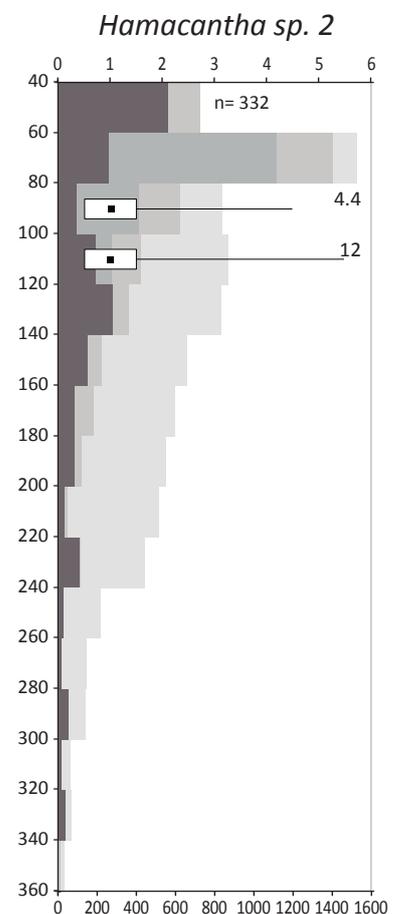
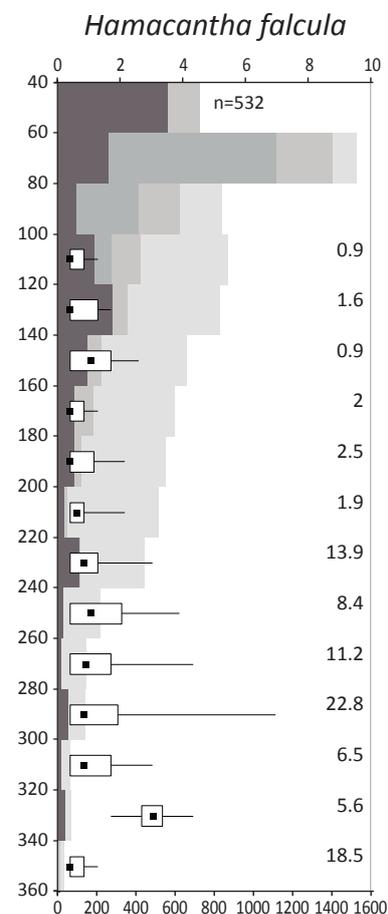
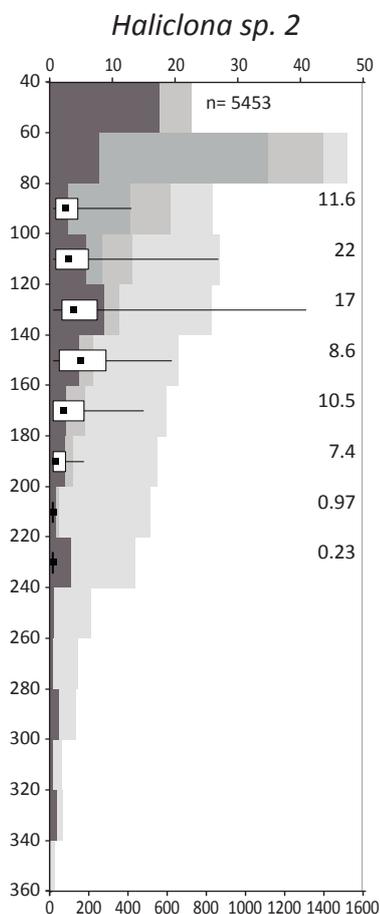
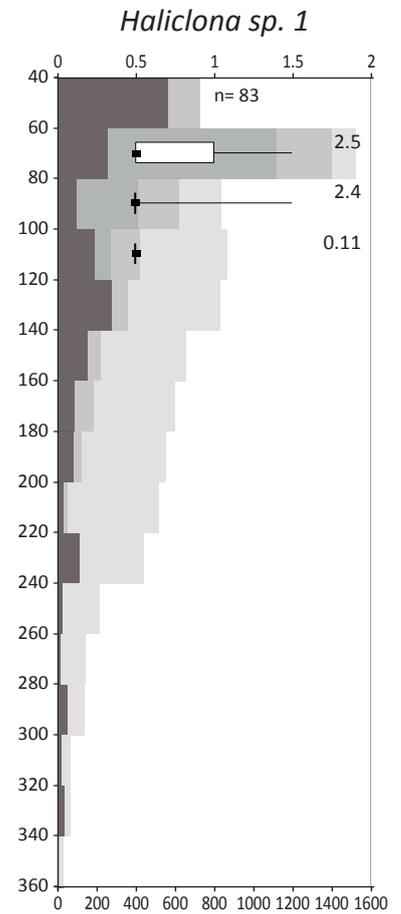
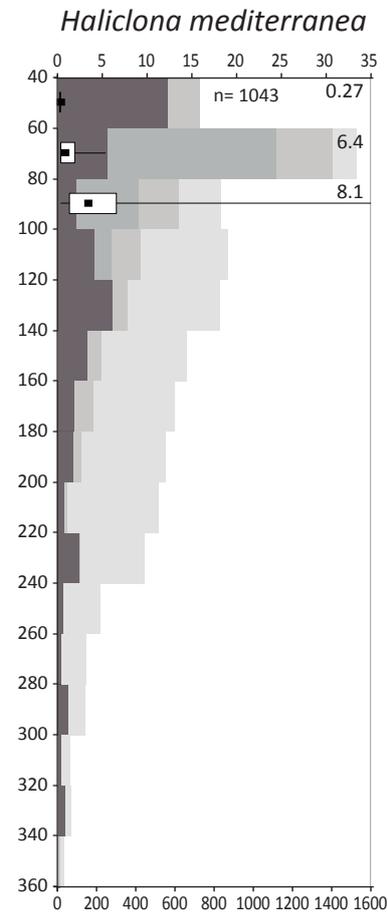
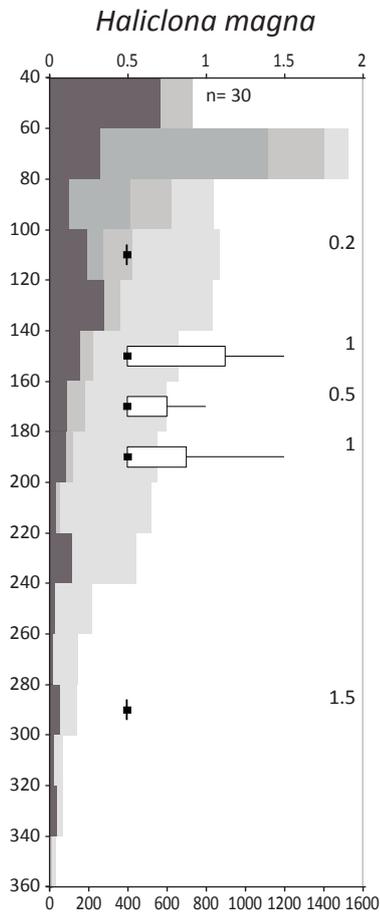
Fig. 3 - Sponge species present in the study area:

(a) *Aaptos aaptos*, (b) *Axinella* sp., (c) *Cf. Dyctionella alonsoi*, (d) *Chondrosia reniformis*, (e) *Haliclona fimbriata*, (f) *Haliclona magna*, (g) *Haliclona mediterranea*, (h) *Haliclona* sp. 1, (i) *Haliclona* sp. 2, (j) *Haliclona elegans*, (k) *Hamacantha falcula*, (l) *Hamacantha* sp. 2, (m) *Hexadella* cf. *deditifera*, (n) *Pachastrella monilifera*, (o) *Phakellia robusta*, (p) *Pocillastra compressa*, (q) *Thenea muricata* (epiphyted by zoanthid).



m=8221

BOTTOM TYPES LEGEND: Sand to Grabble Cobbles & Pebbles Maërl Rock



m=8221

BOTTOM TYPES LEGEND: Sand to Grabble Cobbles & Pebbles Maërl Rock

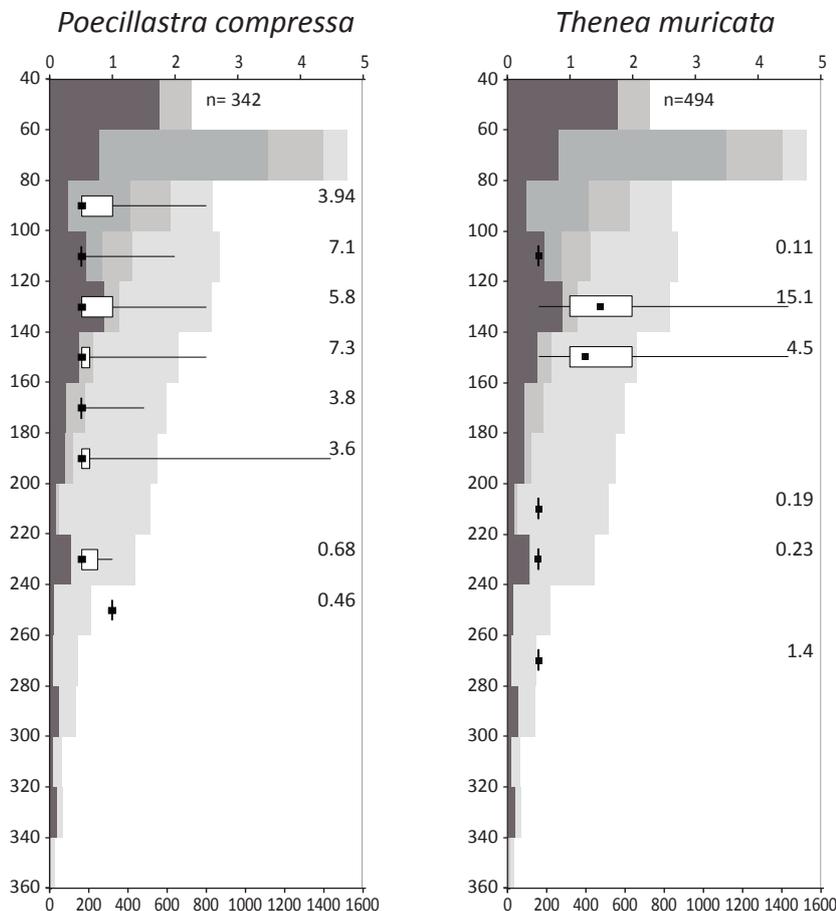
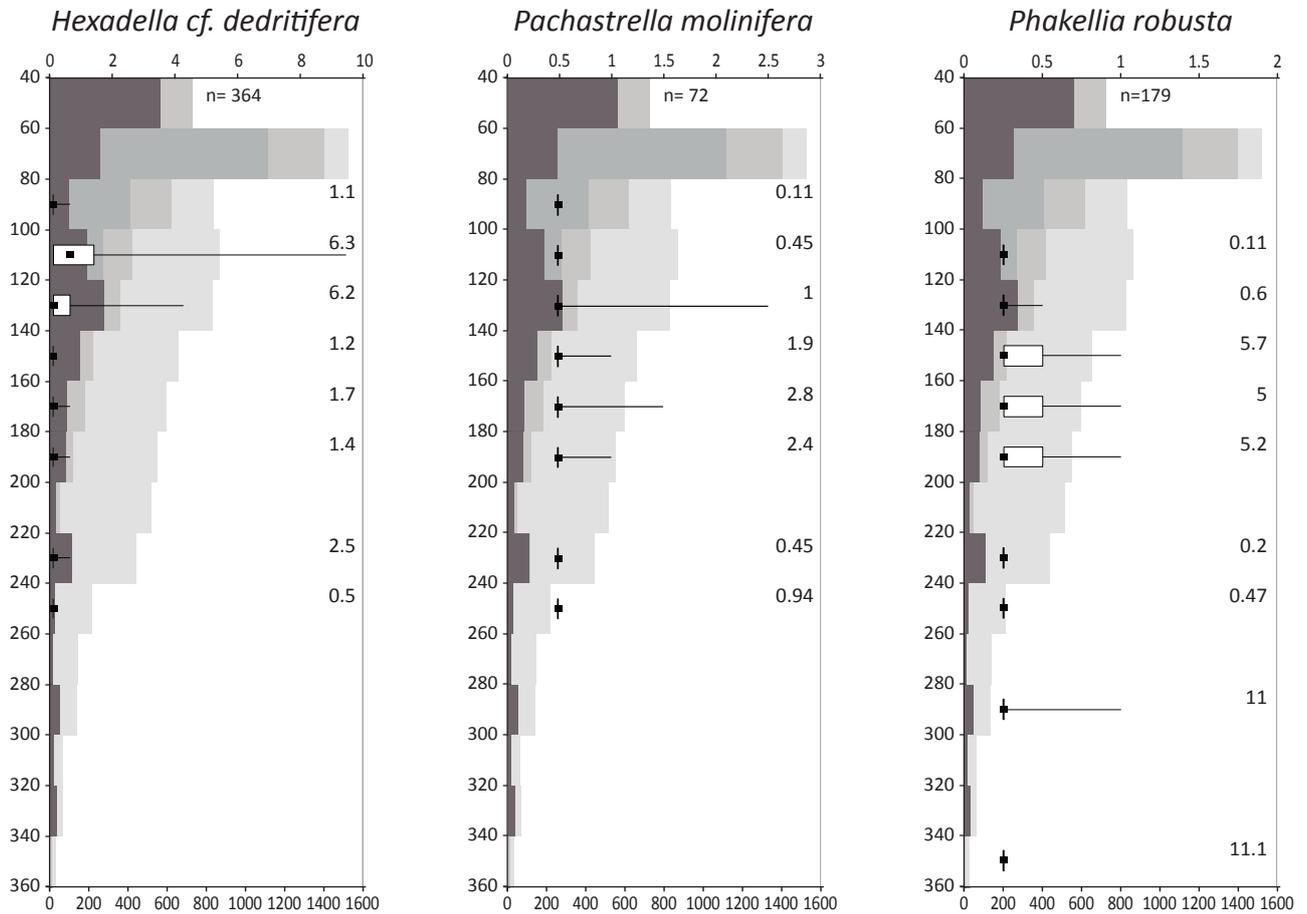


Fig. 4 - Bathymetrical distribution of the density of the species in the study area:

the black square indicates the median value; the box indicates the first and third quartiles; and the line indicates the range between minimum and maximum values. Grey-scale histograms represent the total number of sampling units for each substrate type (see legend) over the studied bathymetrical range. Numbers on the right indicate the percentage of sampling units with presence of the species. Total number of individual (n) are indicated for each species. The number of sampling units (m) was the same for all the species (8221).

m=8221

BOTTOM TYPES LEGEND: Sand to Grabble Cobbles & Pebbles Maërl Rock

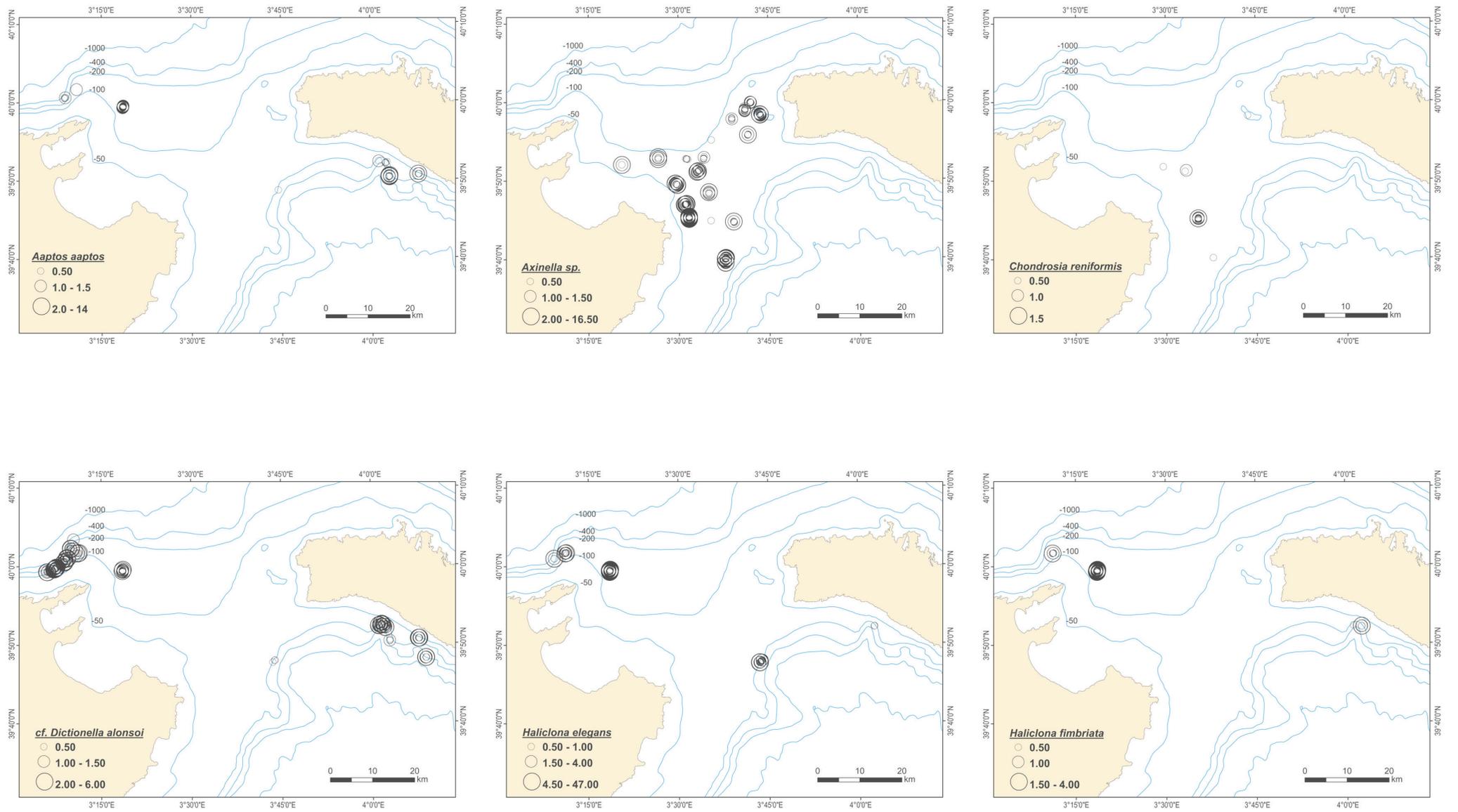


Fig. 5.A - Spatial distribution of *Aptos aptos*, *Axinella sp.*, *Chondrosia reniformis*, *cf. Dictionella alonsoi*, *Haliclona elegans* and *Haliclona fimbriata* in the study area. The bubbles show geographical location and their size is proportional to the density values (ind. /m²).

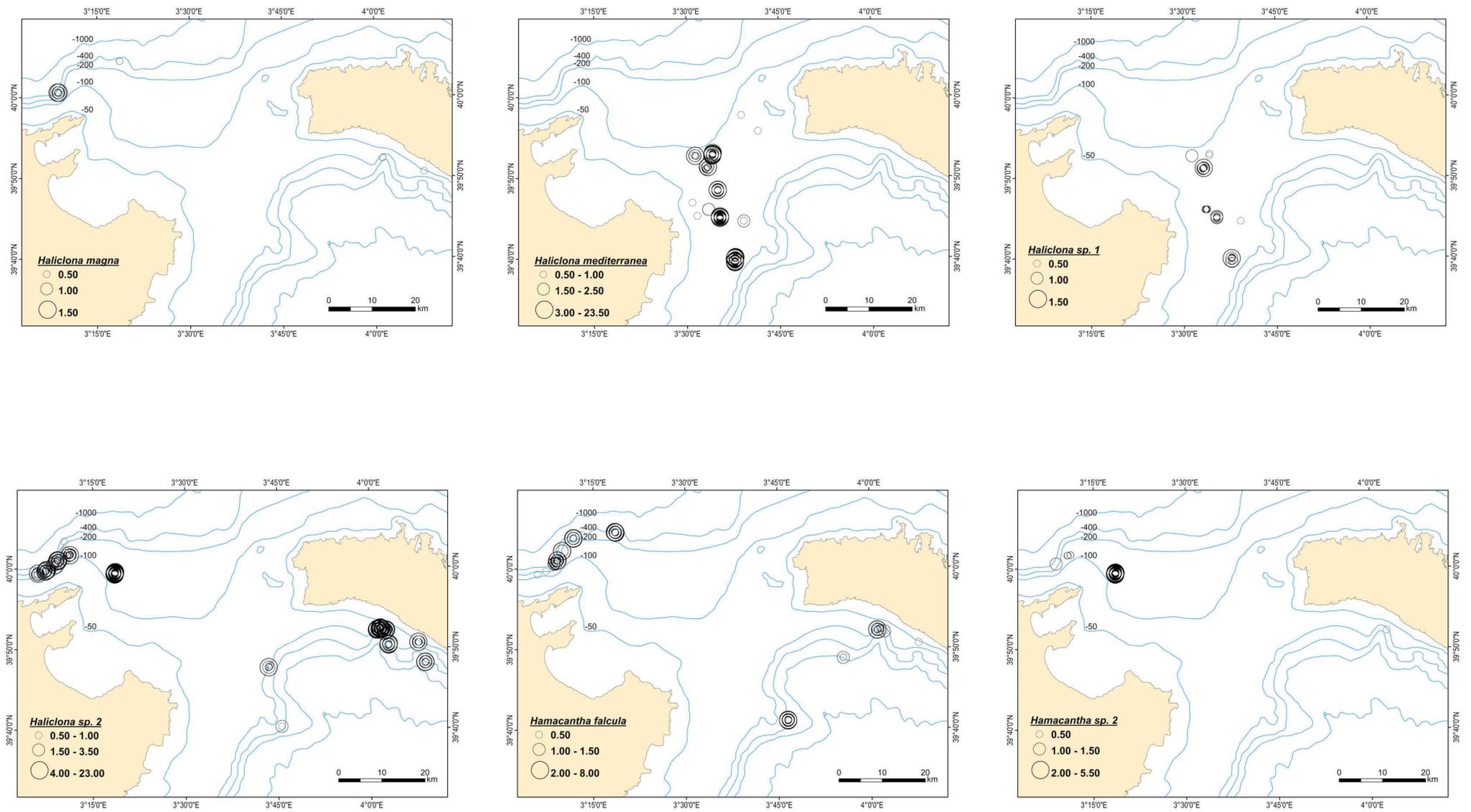


Fig. 5.B - Spatial distribution of *Haliclona magna*, *Haliclona mediterranea*, *Haliclona sp.1*, *Haliclona sp. 2*, *Hamacantha falcata* and *Hamacantha sp. 2* in the study area. The bubbles show geographical location and their size is proportional to the density values (ind. /m²).

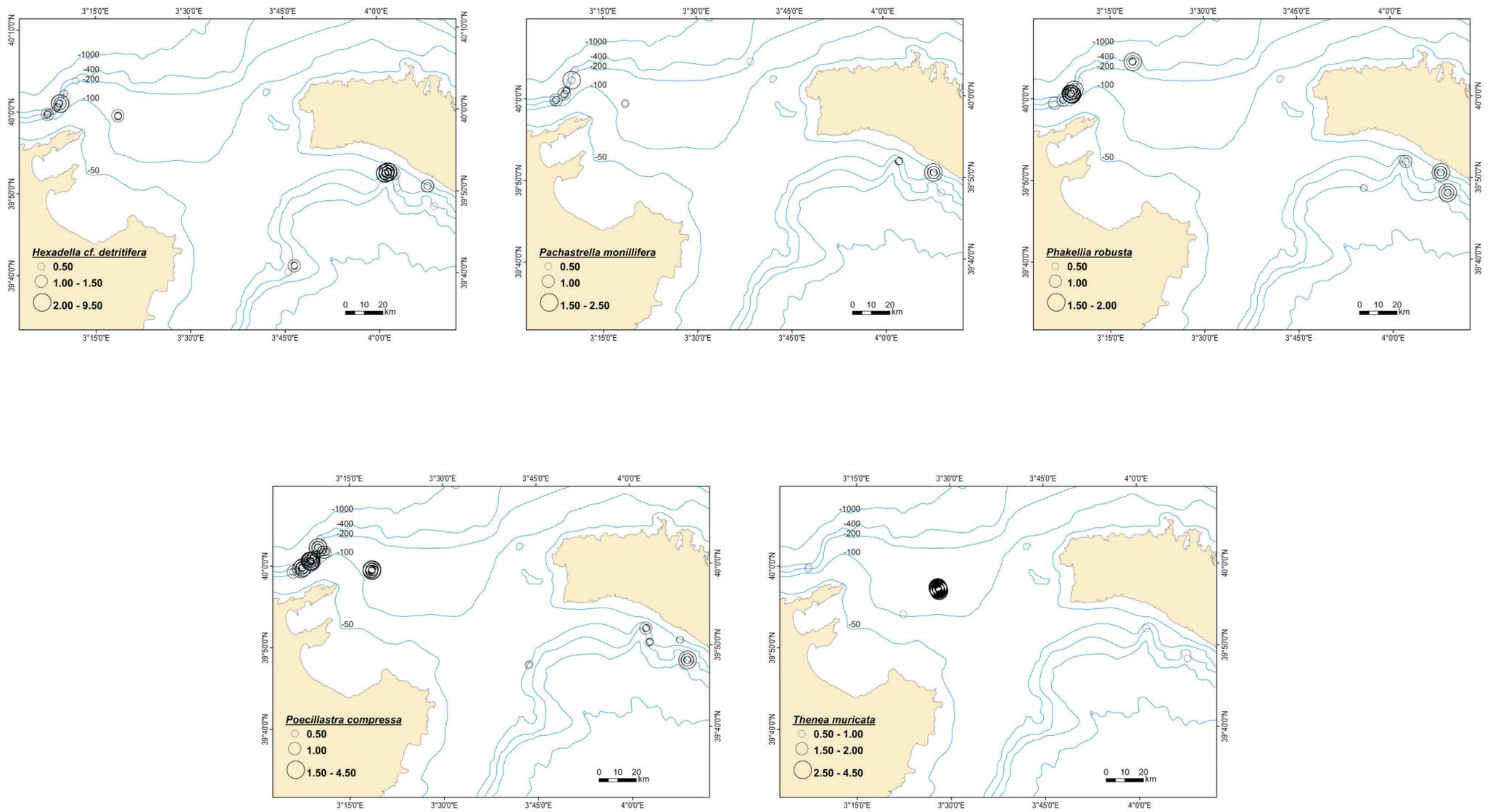


Fig. 5.C - Spatial distribution of *Helladella cf. detritifera*, *Pachastrella monilifera*, *Phakellia robusta*, *Poecillastra compressa* and *Thenea muricata* in the study area. The bubbles show geographical location and their size is proportional to the density values (ind. /m²).