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1 **Megabenthic assemblages in the continental shelf edge and upper**
2 **slope of the Menorca Channel, Western Mediterranean Sea**

3

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22

23

24 **Abstract**

25

26 Highly diverse megabenthic assemblages dominated by passive and active suspension
27 feeders have been recently reported in shelf edge environments of the Mediterranean

28 Sea. Due to their frequent association with species of commercial interest, these
29 assemblages have been heavily impacted by fishing practices. The vulnerability and
30 low resilience of these assemblages, composed mainly by long-living and slow-
31 growing species, have motivated the implementation of management measures such
32 as the restriction of bottom trawling, and the establishment of large protected areas
33 including these environments. The Menorca Channel is one of the areas recently
34 included in the protection frame of the European Union Natura 2000 network.
35 Quantitative analysis of video transects recorded at 95–360 m depth by manned
36 submersible and remotely operated vehicles were used to characterize megabenthic
37 assemblages, and assess their geographical and bathymetric distribution. Six different
38 assemblages were identified, mainly segregated by substrate and depth. Hard
39 substrates hosted coral gardens and sponge grounds, whereas soft sediments were
40 mainly characterized by large extensions of the crinoid *Leptometra phalangium* and
41 the brachiopod *Gryphus vitreus*. The good preservation of most of the observed
42 assemblages is probably related to a low bottom trawling pressure, which mainly
43 concentrates deeper on the continental slope. Because of their biological and
44 ecological value, management and conservation measures need to be established to
45 preserve these benthic assemblages.

46

47 Keywords

48 Mediterranean Sea; continental shelf edge; continental slope; benthic communities;
49 trawling; spatial and vertical distribution.

50

51

52 **1. Introduction**

53

54 Recent technological advances and increased availability of remotely operated
55 vehicles (ROVs), manned submersibles, and video-equipped towed gears have
56 significantly increased accessibility to mid and outer continental shelves, continental
57 slopes and seamounts, thus allowing the direct observation and quantitative study of
58 megabenthic assemblages (e.g. Etiope et al., 2010; Buhl-Mortensen et al., 2016). Rich
59 and highly diverse megabenthic assemblages mostly dominated by passive (e.g.
60 gorgonians, corals and black corals) and active (e.g. sponges) suspension feeders (e.g.
61 Emig, 1997; Bo et al., 2013; Bertolino et al., 2013), have been recently reported on
62 these environments in several locations of the Mediterranean Sea (Deidun et al., 2014;
63 Bo et al., 2009; 2012; 2015). These assemblages provide habitat (Mastrototaro et al.,
64 2010; Porteiro et al., 2013) and act as nurseries (Colloca et al., 2004; Bo et al., 2015)
65 for a wide variety of associated species, many of which are of commercial interest
66 (Abella et al., 2005; Maynou and Cartes, 2012).

67 These assemblages have been largely exposed to long-line and trammel net
68 fishing (Orejas et al., 2009; Sampaio et al., 2012; Mytilineou et al., 2014) as well as to
69 the impacts of bottom trawling, since they are distributed below 50 m depth where
70 bottom trawling is allowed (Council Regulation (EC) No 1967/2006) (Maynou and
71 Cartes, 2012; Fabri et al., 2014). Such fishing practices have dramatic effects on
72 megabenthic structuring species, which are often removed or severely damaged
73 (Fosså et al., 2002; Mytilineou et al., 2014), resulting in a decline in the biodiversity
74 and abundance of the associated fauna (Althaus et al., 2009; Clark et al., 2016). In the
75 Mediterranean Sea, bottom trawling has progressively increased in intensity since the
76 first half of the 20th century and has steadily expanded toward greater depths (Sacchi,
77 2008). Consequently, decades of chronic trawling have widely impacted large areas of

78 the Mediterranean continental shelf and slope (e.g. Fabri et al., 2014), limiting
79 relatively well preserved megabenthic assemblages to remote (Díaz et al., 2015) or
80 inaccessible rough, rocky floors (Bo et al., 2015). The ecological effects of bottom
81 trawling are extremely long lasting, since no recovery of deep megabenthic
82 assemblages dominated by anthozoans have been observed in areas closed to trawling
83 for more than ten years (Althaus et al., 2009; Williams et al., 2010). Due to the slow-
84 growth and high longevity of most of the megabenthic species in these assemblages, it
85 has been suggested that their possible recovery could span from centuries to millennia
86 (Clark et al., 2016).

87 The vulnerability and low resilience of these communities (Althaus et al.,
88 2009) have motivated the recent establishment of managed and protected areas on
89 continental shelves, continental slopes (Spalding et al., 2013; Bennecke and Metaxas,
90 2016) and seamounts (Sheppard et al., 2012; Huvenne et al., 2016) worldwide. In the
91 Mediterranean Sea, the protection of large areas of the continental shelf and slope has
92 been recently proposed as a part of an ecosystem-based management strategy of
93 marine resources and environments, which include the Menorca Channel (European
94 Union, Natura 2000 network, [http://www.eea.europa.eu/data-and-maps/data/natura-](http://www.eea.europa.eu/data-and-maps/data/natura-2)
95 2). Previous studies have investigated and characterized benthic assemblages in the
96 inner continental shelf (< 100 m) of the Menorca Channel (e.g. Joher et al., 2012;
97 Barberá et al., 2012; Grinyó et al., 2016), but the composition and distribution of
98 benthic assemblages on the outer continental shelf and upper slope still remain widely
99 unknown. Additional information is thus fundamental for the establishment of
100 effective management and conservation measures, as well as to monitor their
101 effectiveness.

102 Hence, the aims of this study were: (1) to characterize the composition of

103 megabenthic assemblages (defined here as assemblages constituted by sessile and low
104 motile invertebrates (i.e. echinoderms) larger than 2 cm (e.g. Seike et al., 2013)) on
105 the deep continental shelf and upper slope at 95–360 m depth in the Menorca
106 Channel; (2) to assess their geographical and bathymetric distribution; (3) to quantify
107 their biodiversity variation with depth; and (4) to compare their distribution with the
108 pressure of bottom trawling in the area.

109

110 **2. Materials and methods**

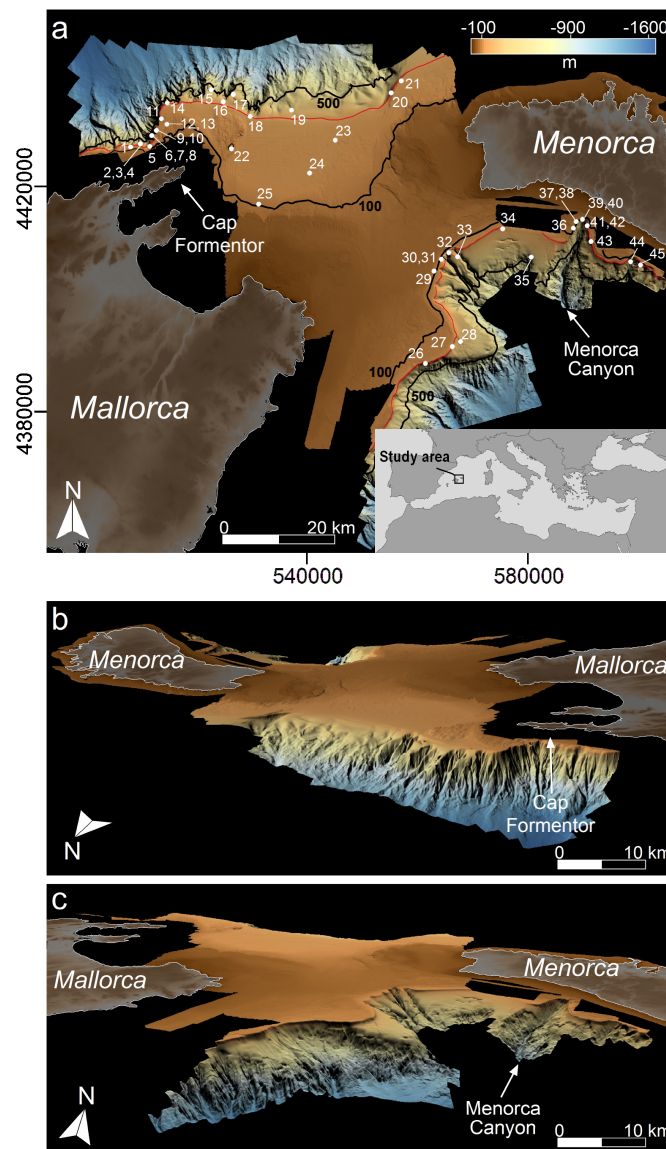
111

112 2.1 Study area

113

114 The Menorca Channel is located in the Western Mediterranean Sea between Mallorca
115 and Menorca islands (39° 53' 0.73" N, 3° 29' 51.16" E) (Fig. 1a), as part of the
116 Balearic Promontory (Acosta et al., 2002). The study area covered the outermost
117 continental shelf (90–110 m), the shelf edge (110–180 m) and the upper slope (180–
118 350 m) of the channel. The continental shelf is characterized by smooth reliefs,
119 covered by maërl beds alternating with outcropping rocks of coralligenous, and
120 detritic coarse sediments (Barberá et al., 2012). Fine sands cover vast areas of the
121 northern part of the investigated section of the continental shelf at 100–110 m depth
122 (Grinyó et al., 2016). Smooth reliefs and large extensions of detritic sediments with
123 few isolated patches of outcropping rocks characterize most of the shelf edge and
124 continental slope (Grinyó et al., 2016). Vertical walls and sharp-edged rocky outcrops
125 are the dominant substrate near Cap Formentor (Fig. 1b) and in the Menorca Canyon
126 head (Fig. 1c) (Grinyó et al., 2016).

127 The northern shelf edge and continental slope of the Menorca Channel is
128 influenced by the Balearic Current (Balbín et al., 2012), which flows northward at
129 approximately 200 m depth (Ruiz et al., 2009). Conversely, the southern shelf edge
130 and upper slope are mostly influenced by the sporadic arrival of mesoscale structures
131 detached from the Algerian Current and the Almería Oran front (Millot, 1987; García
132 et al., 2005).



133
134
135 **Fig. 1.** The study area. (a) Bathymetry of the Menorca Channel: the map shows the location of the
136 video transects (1 to 45) and the location of the study area in the western Mediterranean. Frontal views

137 of the continental slope of the north (b) and south (c) of the Menorca Channel with the continental shelf
138 in the background. Black lines indicate the 100 and 500 m isobath and the red line indicates the shelf
139 edge.

140

141 2.2 Sampling procedure

142

143 A total of 45 video transects (Fig. 1a, Supplementary material 1) were recorded
144 during four surveys conducted on board of the R/V “García del Cid” (September
145 2010, April 2011, October 2011, June 2012): 17 video transects were recorded with
146 the manned submersible JAGO (IFM–GEOMAR) during the first two surveys, and 28
147 video transects were recorded with the NEMO ROV (Gavin Newman) during the last
148 two surveys. Both instruments were equipped with a 1080 horizontal line resolution
149 camera, a manipulator arm and two parallel laser beams (0.5 m and 0.12 m for the
150 JAGO and the NEMO, respectively). Laser beams were used to determine a fixed
151 width of 0.5 m during video analysis and all transects were recorded with a close
152 zoom (~0.5–1.5 m width). Both JAGO and NEMO moved at a constant speed of ~0.3
153 knots, and explored a depth range between 90 to 347 m. The positioning of JAGO and
154 NEMO was achieved with an underwater acoustic positioning system LinkQuest
155 TrackLink 1500 HA. Transects were haphazardly located in order to cover the entire
156 study area, but areas showing morphological features possibly related to the presence
157 of rocky bottoms were explored more intensively (Fig. 1). Overall, a total seabed
158 length of 37.7 km was video recorded.

159 In order to confirm the taxonomic identification of the megabenthic organisms
160 observed in the video transects, organisms of all 69 species considered in this study
161 were collected by means of the JAGO and the NEMO manipulator arm, and
162 epibenthic sledges equipped with video cameras. Sampled organisms were fixed and

163 preserved in 10% formalin as well as in absolute ethanol for posterior taxonomical
164 and genetic analyses. Organisms were identified to the lowest possible taxon, which
165 corresponded to species or genus.

166

167 2.3 Video analysis

168

169 Quantitative video analysis was performed according to the methodology described
170 by Gori et al., (2011) and Grinyó et al., (2016), using Apple's Final Cut Pro software.
171 The length of each transect was estimated based on the records from the acoustic
172 positioning system (see details in Grinyó et al., 2016). Sequences with poor image
173 quality or too far away from the seafloor were considered unsuitable for analysis. The
174 remaining useful sequences comprised 93.3% of the total recorded material and
175 corresponded to a total distance of 35 km. The position of all megabenthic organisms
176 observed within a width of 0.5 m (estimated video coverage based on the laser beams)
177 was defined by the time elapsed since the beginning of the video transect to the
178 crossing of the laser beams by the organism (see details in Grinyó et al., 2016).
179 Seabed substrate type was classified (based on the Wentworth scale) into five
180 categories: fine sand, medium sand to gravel, cobbles and pebbles, maërl, and rock.
181 Seabed slope was classified into three categories: horizontal (0°–30°), sloping (30°–
182 80°), or vertical (80°–90°); slope was estimated from the video by looking at the depth
183 sensor (Gori et al., 2011; Ambroso et al., 2013; Grinyó et al., 2016).

184

185 2.4 Data treatment

186

187 2.4.1 Sampling unit characterization

188

189 Each transect was divided into a string of sampling units. Several sampling unit sizes
190 (2, 5, 10, 15, 20, 30, 40 and 50 m²) were used in the canonical correspondence
191 analysis (see below) in order to explore how sampling unit size may affect the
192 identification of the benthic assemblages, and their associated main environmental
193 features. Each sampling unit was characterized by the number of megabenthic
194 organisms of each identified species (density = number of individuals per m²), as well
195 as by the average depth and coverage percentage for each substrate and slope
196 category.

197

198 2.4.2 Canonical correspondence analysis

199

200 Canonical correspondence analysis (CCA) is a multivariate constrained ordination
201 technique used to elucidate the relationships between species abundances (response
202 variables) and environmental variables (explanatory variables) (Ter Braak, 1986;
203 Greenacre and Primiceiro, 2013). CCA was used to define megabenthic assemblages
204 based on species composition, and to explore their relationship with the three
205 environmental factors obtained from the video transects: substrate, depth, and slope.
206 Since recording of video transects was restricted in time, other environmental
207 variables such as seawater temperature, turbidity or fluorescence could not be
208 considered in this study because they can show high seasonal variability
209 (consequently, any possible correlation between such variables and the observed
210 benthic assemblages would have been highly fortuitous). Taxa that appeared with less
211 than three individuals were discarded from the analysis in order to avoid distortions.
212 Depth of sampling units was coded into four fuzzy categories that preserve all the

213 information in the variables while reducing it to a categorical scale (Aschan et al.,
214 2013). Such fuzzy-coding takes into account possible nonlinear relationships between
215 fauna abundance and depth (Greenacre and Primiceiro, 2013). The mean depth of
216 each of the four fuzzy categories are as follow: dep1 = 106 m, dep2 = 130 m, dep3 =
217 188 m, and dep4 = 252 m. No transformation was applied to either environmental or
218 biological data. The CCA was performed with the function `cca` in the `vegan` package
219 (Oksanen et al., 2015) of the R software platform (R Core Team 2015). Additionally,
220 substrate, depth, and slope were tested to determine which was the best predictor by
221 means of the R function `anova` in the `vegan` package (Oksanen et al., 2015). Due to
222 the lack of previous information about sampling unit size for the characterization of
223 Mediterranean megabenthic assemblages in the outer continental shelf and upper
224 slope by means of quantitative video analysis, CCA was performed with different
225 sampling unit sizes (2, 5, 10, 15, 20, 30, 40 and 50 m²).

226

227 2.4.3 Megabenthic assemblages distribution and depth-related diversity

228

229 The geographical distribution of each identified megabenthic assemblage in the study
230 area was reported by mapping its occurrence in the video transects on a
231 geographically referenced map using GIS (ESRI ArcGIS ArcInfo v10). The
232 bathymetric distribution of each assemblage was represented in 5 m depth intervals.
233 To compare species' turnover (or beta-diversity) among the outer continental shelf
234 (90–110 m depth), the shelf edge (110–180 m depth) and the upper slope (180–347 m
235 depth) randomized species accumulation curves were calculated (Vetter et al., 2010;
236 De Leo et al., 2014), using the statistical software R and the "vegan" package.
237 The method used finds the mean species accumulation curves and their standard

238 deviation from random permutations of data ($n = 100$), which avoids distortions in the
239 curves due to variations in species abundance and sampling effort (Gotelli and
240 Colwell, 2001).

241

242 2.4.4 Fishing activity in the study area

243

244 Fishing activity and location of fishing grounds (i.e. areas consistently fished through
245 time) in the study area were assessed by means of Vessel Monitoring System (VMS)
246 location data through the analysis of the number of fishing events per surface units.
247 VMS data were obtained in the framework of the LIFE+ INDEMARES project from
248 the General Directorate of Fisheries Management of the Spanish Ministry of
249 Agriculture, Food and Environment (MAGRAMA). Available VMS records from
250 January 2007 to July 2012 were included after examination to exclude erroneous
251 vessel identity, position or speed. To select the records referring to fishing activity, a
252 set of common criteria (Lee et al., 2010) was followed: duplicated records and records
253 close to ports were removed, and the interval between records was calculated in order
254 to only retain vessels moving at 2–3.5 knots, so that only vessel locations while
255 trawling are represented. The distribution of fishing activity in the study area was
256 assessed based on fishing events counts per cell unit based on a point summation
257 method (Hintzen et al., 2010). A 250 m² cell was selected as the most suitable size
258 considering geographical factors and the available dataset (for further details, see Piet
259 and Quirijns, 2009). Only one record per vessel, day and cell was retained to avoid
260 overestimation of fishing activity (Hintzen et al., 2010). The centroids of each cell
261 were extracted and weighted by the sum of fishing events for this cell. These
262 weighted centroids were used to identify statistically significant hot spots of fishing

263 activity in the study area using the G_i^* statistic (Getis and Ord, 1996).

264

265 **3. Results**

266

267 A total of 69 megabenthic species belonging to seven phyla and twelve classes were
268 identified in the study area (Supplementary material 3).

269

270 3.1 Canonical Correspondence Analysis (CCA)

271

272 CCA analysis performed with different sampling unit sizes revealed a general
273 increase in the amount of inertia explained (i.e. explained variation of the data) by
274 environmental factors as sampling unit size increased (Table 1). However, as
275 sampling unit size increased, the resolution of the CCA output decreased (Table 1,
276 Supplementary material 2). This was due to: (1) a reduction in the total number of
277 sampling units, (2) an increase in the number of sampling units discarded from the
278 analysis because affected by unsuitable sequences, and (3) an increased variability of
279 each sampling unit composition (due to the presence of several bottom types in large
280 sampling units) (Table 1). A 5 m² sampling unit size was chosen as the best balance
281 between the inertia explained by environmental factors, and the number of
282 megabenthic assemblages identified (Table 1). This size exceeds those previously
283 used for shallow Mediterranean environments (e.g. Weinberg, 1978; Coppari et al.,
284 2016), probably due to the wider range of environmental gradients and the much
285 larger number of species included in this study.

286

287 **Table 1** Results of the CCA analysis performed at different sampling unit size (env. fact. = environmental factors).

Sampling unit size	Species number	Organism number	Sampling units number	Total inertia	Restricted inertia	Unrestricted inertia	% of inertia explained by env. fact.	Macrobenthic assemblage number
2	69	39138	8639	28.36	3.03	25.32	10.69	6
5	69	38230	3372	20.96	3.28	17.68	15.6	6
10	69	32829	1537	18.5	3.39	15.11	18.3	5
15	69	31632	985	16.15	2.46	13.69	15.2	5
20	69	31358	713	15.17	3.44	11.73	22.6	5
30	69	27658	443	13.8	3.45	10.37	24.97	5
40	67	26023	316	13.25	3.57	9.67	13.25	5
50	67	20855	248	12.59	3.61	8.98	28.71	4

289

290 Using 5 m² sampling units, a total of 38230 organisms belonging to 69 megabenthic
291 species were considered in the analysis (Table 1). Crinoidea, exclusively represented
292 by the species *Leptometra phalangium*, was the most abundant and the third most
293 frequent class accounting for 31.8% of all observed organisms, occurring in 16.3% of
294 all sampling units (Table 2). Demospongiae, represented by 21 species
295 (Supplementary material 3), was the second most abundant and the second most
296 frequent class, accounting for 30.9% of all observed organisms, in 27.7% of all
297 sampling units (Table 2). The class Anthozoa, represented by 27 species
298 (Supplementary material 3), was the third most abundant and the first most frequent
299 class, accounting for 21% of observed organisms, in 29.8% of all sampling units
300 (Table 2). The remaining taxa were represented by 1–4 species (Supplementary
301 material 3), accounting for 0.02–8.2% of observed organisms, in 0.2–14.5% of all
302 sampling units (Table 2).

303

304 **Table 2** Macrobenthic taxa occupancy and abundance in the study area. Occupancy (frequency of occurrence in the set of
305 sampling units); abundance (number of organisms). (subc. = subclass).

306

Phylum	Class	Species number	Occupancy		Abundance	
			Number	(%)	Number	(%)
Porifera	Demospongiae	21	936	27.76	11805	30.96
Cnidaria	Anthozoa	27	1004	29.8	8031	21
	Hydrozoa	3	14	0.42	16	0.04
Bryozoa	Gymnolaemata	1	31	0.92	47	0.12
Brachiopoda	Rhynchonellata	1	467	13.85	3219	8.20
Annelida	Polychaeta	4	491	14.56	2334	6.12
	Echiura	1	49	1.45	55	0.14
Echinodermata	Crinoidea	1	549	16.28	12126	31.8
	Ophiuroidea	1	64	1.90	416	1.09
	Echinoidea	4	127	3.77	144	0.38
	Holothuridae	2	15	0.44	15	0.04
	Astroidea	1	11	0.33	12	0.03
Chordata	Asciacea	2	4	0.18	10	0.02

307

308 In the CCA performed using 5 m² sampling units, environmental factors explained
309 15.6% of the variation in species abundance. The first axis (CCA1) explained 26.8%
310 of the variance, and the second axis (CCA2) explained 22.7% of the variance.
311 Substrate was the best predictor (inertia = 2.19) followed by depth (inertia = 1.30),
312 and slope (inertia = 0.70). Six different megabenthic assemblages (Fig. 2a),
313 characterized by environmental factors (Fig. 2b) and most contributing species (Fig.
314 2c) were identified in the CCA analysis, for which illustrative in situ pictures (Fig. 3)
315 and geographic (Fig. 4) and bathymetric distribution (Fig. 5) are also provided:

316

317 Assemblage A: occurring on shallow (95–110 m depth) maërl beds alternated with
318 small patches of coralligenous outcrops (Fig. 2b), is mostly characterized by the
319 sponges *Haliclona cf. elegans* and *Aplysina cavernicola* (Figs. 2c, 3a 3b and
320 Supplementary material 4).

321

322 Assemblage B: occurring on horizontal grounds covered by fine and coarse sands
323 throughout most of the explored depth range (110–280 m depth) (Fig. 2b), is mostly
324 characterized by the presence of the crinoid *Leptometra phalangium* (Figs. 2c, 3c and
325 Supplementary material 5).

326

327 Assemblage C: occurring on horizontal grounds covered by medium sand to gravel
328 from shallow to deep (110–330 m depth) environments (Fig. 2b), is characterized by
329 the presence of the brachiopod *Gryphus vitreus* (Figs. 2c, 3d and Supplementary
330 material 6).

331

332 Assemblage D: mostly found at shallow and intermediate depth (95–140 m depth) on
333 mixed cobbles and pebbles bottoms (Fig. 2b), is characterized by the polychaete
334 *Salmacina dysteri* and two unidentified sponge species belonging to the genus
335 *Hamacantha* and *Haliclona* (Figs. 2c, 3e, 3f and Supplementary material 7).

336

337 Assemblage E: occurring in sloping rocky outcrops from shallow to deep
338 environments (95–337 m depth) (Fig. 2b), is characterized by the presence of the
339 gorgonians *Eunicella cavolinii*, *Viminella flagellum*, the soft coral *Nidalia studeri*, the
340 solitary coral *Thalamophyllia gasti* and the encrusting sponge *Hamacantha falcula*
341 (Figs. 2c, 3g, 3h, 3i, 3j, 3k and Supplementary material 8).

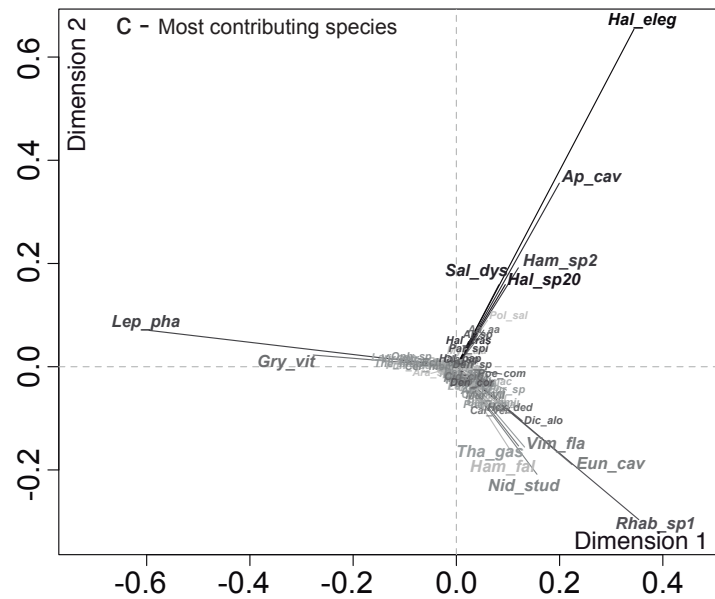
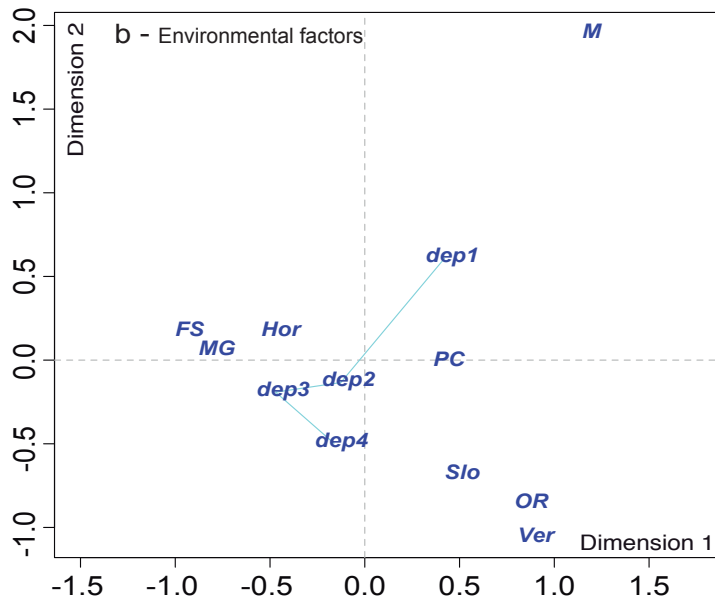
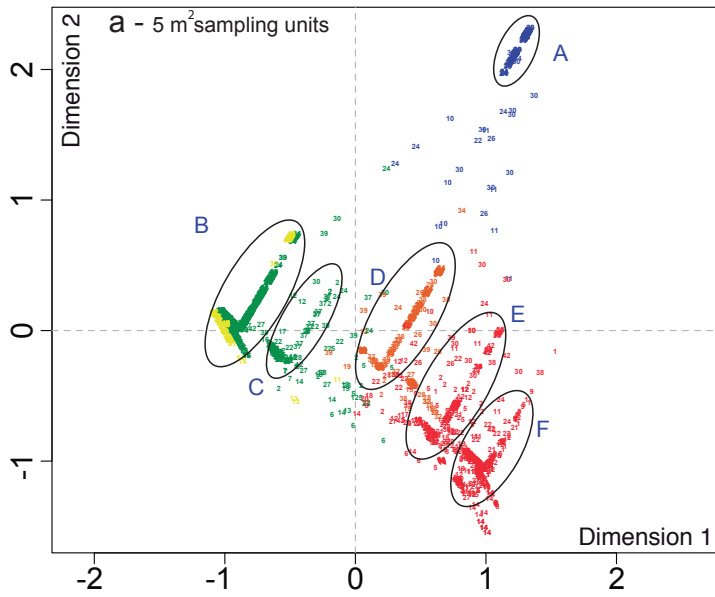
342

343 Assemblage F: occurring on vertical rock outcropping mostly at shallow and
344 intermediate (95–210 m depth) environments (Fig. 2c), is characterized by an

345 incrusting sponge of the genus *Rhabderemia* (Figs. 2c, 3l and Supplementary material

346 9).

347



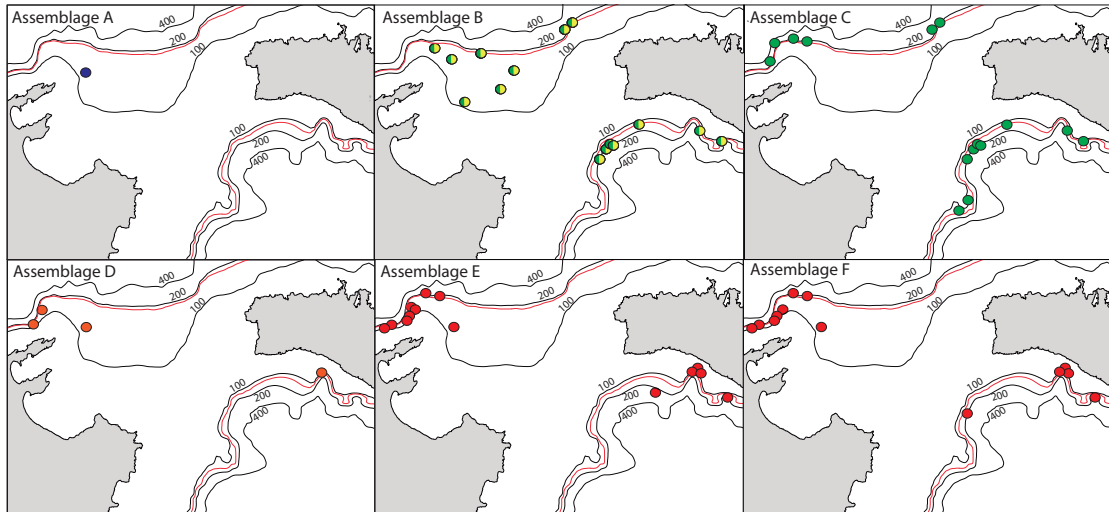
349 **Fig. 2.** Canonical correspondence analysis (CCA) ordination biplots of megabenthic species. In figure
350 2a the biplot shows the distribution of the sampling units (n = 3372), sampling units are colored
351 according to the dominant substrate: fine sands (yellow), medium sands to gravels (green), cobbles and
352 pebbles (orange), maërl (blue), outcropping rock (red). In figure 2b the biplot shows the substrate type
353 (FS = fine sands, MG = medium sands to gravels, PC= cobbles and pebbles, M = maërl, OR =
354 outcropping rock), seabed slope (Hor = horizontal, Slo = slopping, Ver = vertical) and depth, being
355 dep1 the shallowest and dep4 the deepest. In figure 2c the biplot shows the contribution of the different
356 species to the megabenthic assemblages, the scale of greys in the vectors indicate the degree of
357 correlation, being in black the highest correlation degree. Hal_eleg = *Haliclona cf. elegans*, Ap_cav =
358 *Aplysina cavernicola*, Ham_sp2 = *Hamacantha* sp., Hal_sp20 = *Haliclona* sp., Sal_dys = *Salmacina*
359 *dysteri*, Lep pha = *Leptometra phalangium*, Gry_vit = *Gryphus vitreus*, Tha_gas = *Thalamophyllia*
360 *gasti*, Ham_fal = *Hamacantha falcula*, Vim fla = *Viminella flagellum*, Eun_cav = *Eunicella cavolinii*,
361 Nid_stud = *Nidalia studeri*, Rhab_sp2 = *Rhabderemia* sp.

362

363 3.2 Spatial and bathymetric distribution of megabenthic assemblages

364

365 Assemblage A was only observed in one single transect in the north eastern side of
366 the Menorca Channel (Fig. 4) and presented the narrowest bathymetric distribution
367 (95–110 m depth) (Fig. 5). Assemblages B and C were widely distributed in both the
368 northern and southern areas of the channel occurring between 110 and 180 m depth
369 and between 110 and 240 m depth, respectively (Fig. 4). Assemblage D was observed
370 in only four locations in the channel, three in the northern side and one in the head of
371 the Menorca Canyon (Fig. 4), and partially coincided with assemblages A, E and F.
372 This assemblage was distributed between 95 and 140 m depth (Fig. 5). Finally,
373 assemblages E and F mostly co-occurred in transects located in the proximity of Cap
374 Formentor and the Menorca Canyon's head (Fig. 4). However, assemblage E
375 presented a shallower distribution respect to assemblage F that reached the deepest
376 areas of the channel (340 m depth) (Fig. 5).



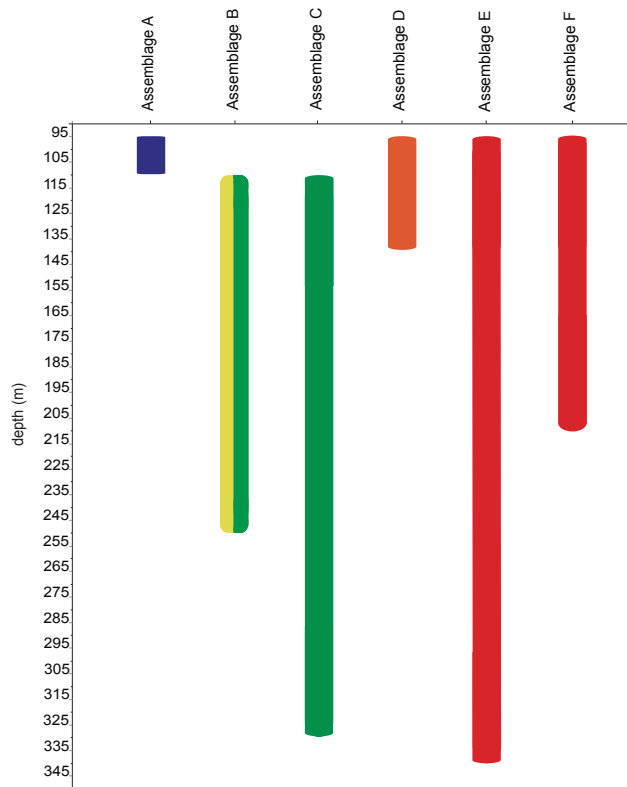
377

378 **Fig. 4.** Spatial distribution of megabenthic assemblages observed in the study area. Assemblages were

379 represented on the study area based on the transects where they occur, and following the colours as in

380 Figure 2a. Grey line represents the 100, 200 and 400 m isobath, red line represents the shelf edge.

381



382

383

384 **Fig. 5.** Bathymetric distribution of the megabenthic assemblages observed in the study area.

385 Assemblages were represented based on the colour as in Figure 2a.

386

387 3.3 Variation of megabenthic diversity with depth

388

389 The highest species turnover is found in the shelf edge (110–180 m depth), followed

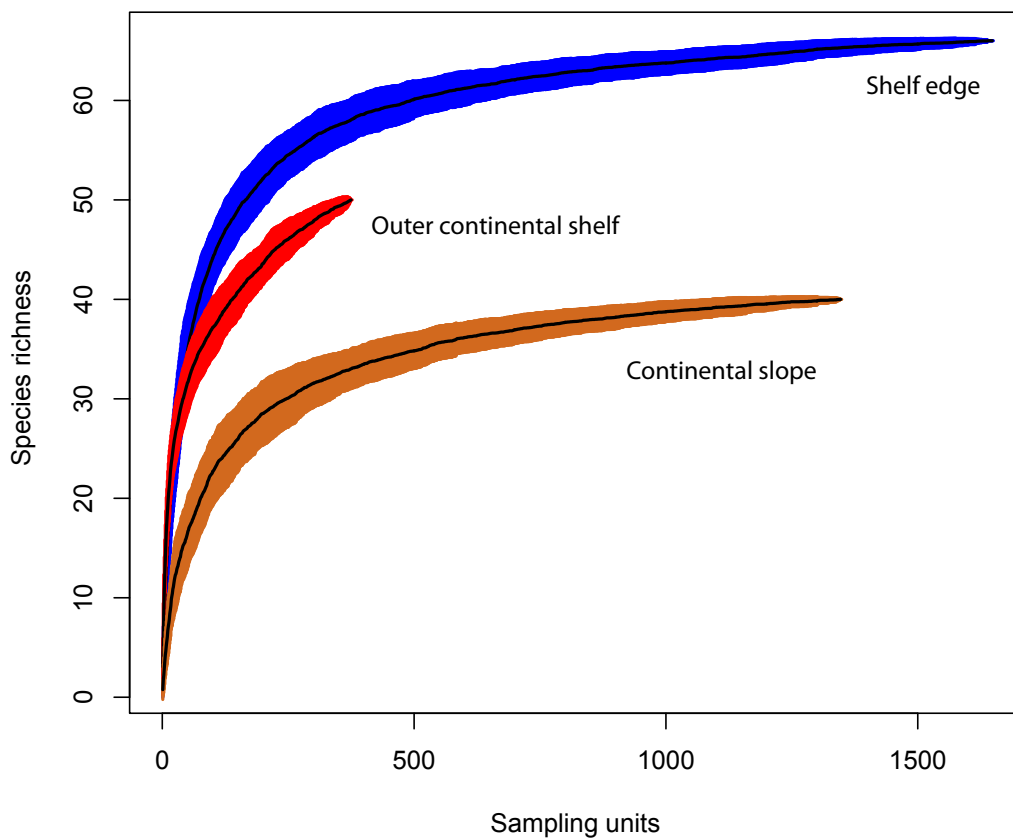
390 by the outer continental shelf (90–110 m depth) and continental slope (180–347 m

391 depth) (Fig. 6). Both shelf edge and continental slope species accumulation curves

392 reach asymptote, highlighting that both depth ranges were representatively sampled.

393 Conversely, species accumulation curve for the outer continental shelf does not reach

394 an asymptote as a consequence of limited sampling.



395

396 **Fig. 6.** Mean species accumulation curve calculated for the outer continental shelf (red), the shelf edge

397 (blue) and the continental slope (orange).

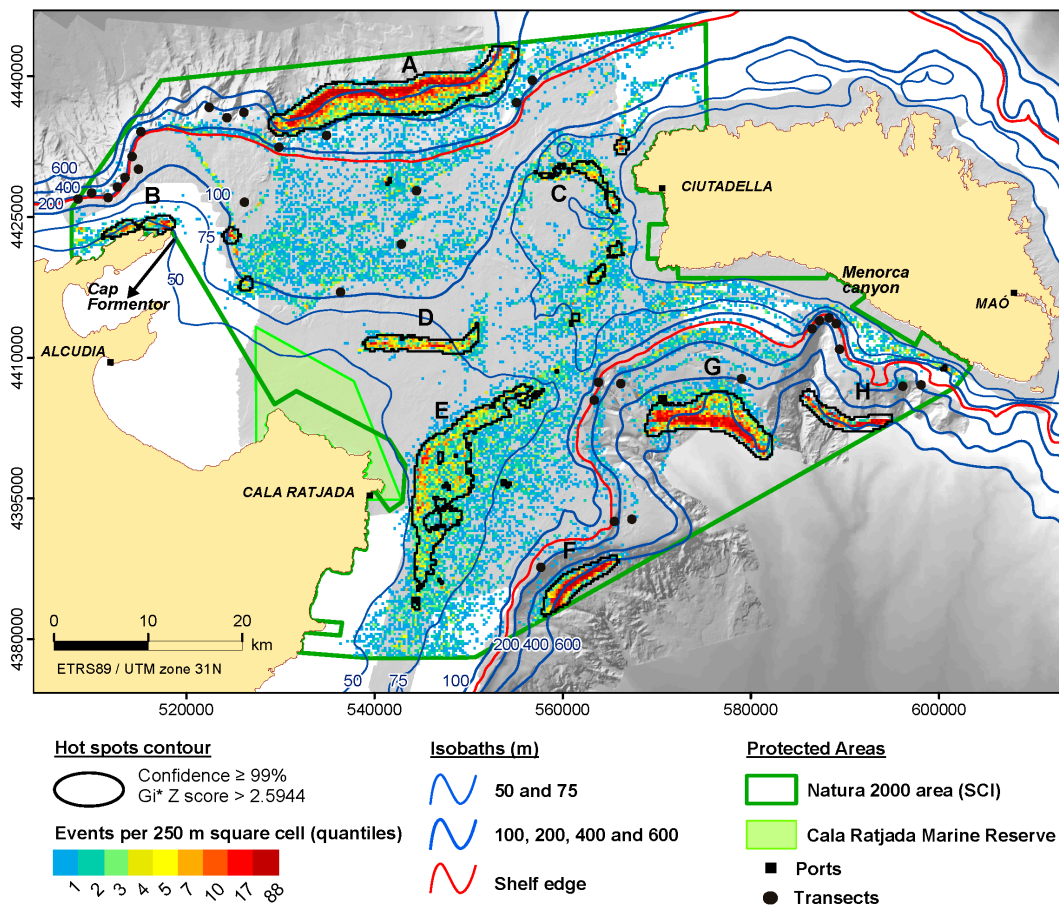
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399

400

401 3.4 Fishing activity in the study area

402 A total of 34 fishing vessels from eleven ports trawled the Menorca Channel's sea
 403 floor from January 2007 to July 2012, according to VMS data. Vessels from the ports
 404 of Cala Ratjada, Alcúdia and Ciutadella (Fig. 7) accounted for 80.3% of the VMS
 405 fishing events. One large (E) and two small (D and C) hot spot areas of bottom
 406 trawling were identified on the continental shelf of the channel at 50–75 m depth (Fig.
 407 7). Four additional small and large hot spots were identified deeper on the continental
 408 slope in the north (A) and south openings (F, G and H) of the channel at 500–600 m
 409 depth (Fig. 7). Finally, a small hot spot area was also observed near Cap Formentor
 410 (B) at ~50 m depth (Fig. 7). Three hot spots (A, E and G) concentrated 73% of the
 411 total bottom trawling fishing effort in the area.



412

413 **Fig. 7.** Bottom trawling effort in the Menorca Channel. Vessel speed has been filtered to the 2-3.5

414 knots range so that only vessel locations while trawling are represented. Colors are proportional to

415 trawling effort (see legend) and hot spot areas (identified using the G_i^* statistic) are surrounded in
416 black lines and indicated by capital letters. Video transects are represented by black dots, and the area
417 included as Site of Community Interest in the Natura 2000 network is indicated by the green line. None
418 of the video transects considered in this study are located in the VMS hot spot areas.

419

420 **4. Discussion**

421

422 The six megabenthic assemblages identified in the study area are distributed
423 throughout the outermost continental shelf and upper slope of the Menorca Channel,
424 and are mainly segregated by substrate type and depth.

425 Sponge grounds composed by large demosponge species (>15 cm in height),
426 mostly characterized by the branched *Haliclona* cf. *elegans* and the tubular sponge
427 *Aplysina cavernicola* (Assemblage A), occur on a shoal located near the shelf edge
428 off Cap Formentor at 95–110 m depth (Fig. 4). This shoal presents a highly irregular
429 topography of vertical walls alternating with areas covered by maërl and
430 coralligenous outcrops. The close proximity of the shoal to the shelf edge (Fig. 4), and
431 its highly irregular topography, are in keeping with deep sponge grounds distribution
432 in the Mediterranean Sea (Bertolino et al., 2015) and in other areas of the world (e.g.
433 Klitgaard and Tendal, 2004; Maldonado et al., 2016). It has been suggested that the
434 irregular topography of these environments may cause the acceleration of local
435 currents (Rice et al., 1990) potentially favouring the presence of sponges (Beazley et
436 al., 2015). *A. cavernicola* and *H. cf. elegans* account for 73% of all observed
437 organisms, followed by other demosponge species such as *Poecillastra compressa*,
438 *Aaptos aaptos* and *Siphonochalina* sp., representing 21% of the observed organisms.
439 Species composition resembles that of other sponge grounds from flat rocky shoals

440 exposed to moderated currents, and high silting (derived from river discharge),
441 between 70 and 130 m depth in the Gulf of Santa Eufemia (southern Tyrrhenian Sea)
442 (Bertolino et al., 2013). Overall, sponge density (9.2 ± 8.4 individuals m^{-2} (mean \pm
443 SD), max = 43 individuals m^{-2}) is similar to those observed in other Mediterranean
444 sponge grounds (Bo et al., 2011a), exceeding those observed in deep multispecific
445 sponge grounds in the North Atlantic (Kutti et al., 2013; Howell et al., 2016). The
446 lack of gorgonians (only represented by a few colonies of *Paramuricea macrospina*)
447 and antipatharians distinguishes this assemblage from Assemblage E, in which almost
448 all the same sponge species (except *A. cavernicola*) co-occur together with large
449 gorgonians and antipatharians (see below) (Supplementary material 3).

450 *Leptometra phalangium* beds (Fig. 3c) are widely distributed between 110 and
451 250 m depth in areas covered with both coarse and fine sands (Assemblage B),
452 agreeing with previous reports from detritic bottoms of the Western Mediterranean
453 shelf edge (e.g. Pérès, 1967; Michez et al., 2014). *L. phalangium* may reach very high
454 densities of more than 30 individuals m^{-2} (5.3 ± 3.2 individuals m^{-2} (mean \pm SD)), as
455 previously observed on detritic substrates at the foot of seamounts in the Tyrrhenian
456 Sea (Bo et al., 2010). In the Menorca Channel, this almost monospecific assemblage
457 (*L. phalangium* represents 95% of all observed organisms) mostly occurs on the shelf
458 edge (96% of occupied sampling units) (Fig. 4), in agreement with studies identifying
459 it as a typical shelf edge assemblage (e.g. Fredj, 1964; Kallianiotis et al., 2000;
460 Mangano et al., 2010). It has been suggested that *Leptometra* beds are mainly
461 constrained to shelf edge environments as they depend upon the exposure to bottom
462 currents that regularly carry high concentrations of suspended organic particles
463 (Lavaleye et al., 2002; Colloca et al., 2003). Absence of trawling activity is
464 fundamental for the persistence of high-density *L. phalangium* populations since the

465 fragility of this organism makes it extremely vulnerable to mechanical damage (Smith
466 et al., 2000). *L. phalangium* populations impacted by bottom trawling on the Cretan
467 continental shelf presented significantly lower densities five months after trawling
468 than non-impacted ones, suggesting a low recovering capacity (Smith et al., 2000).
469 Facies of *L. phalangium* have been associated with elevated densities of
470 benthopelagic fish, with high juvenile abundances, suggesting that this assemblage
471 may play a crucial role in the life cycle of numerous fish species, some of which are
472 of high commercial interest (e.g., *Merluccius merluccius* and *Mullus barbatus*) (Colloca
473 et al., 2004). The sea pen *Funiculina quadrangularis*, the polychaete *Lanice*
474 *conchilega* and the anemones *Cerianthus membranaceus* and *Arachnanthus*
475 *oligopodus* accompany *L. phalangium* on coarse sands. In submarine canyons of the
476 Western Mediterranean *C. membranaceus* and *F. quadrangularis* have also been
477 reported to occur alongside facies of *L. phalangium* (Würtz, 2012). *F. quadrangularis*
478 presents a sparse distribution and occurs at low densities (0.6 ± 0.3 colonies m^{-2} (mean
479 \pm SD), max = 2.5 colonies m^{-2}) contrasting with observations in bathyal
480 environments, where this species forms dense facies (Pérès and Picard, 1964). In fine
481 sand environments, *L. phalangium* generally occurs along with the sea pen *Virgularia*
482 *mirabilis*, the soft coral *Alcyonium palmatum*, and the sponge *Thenea muricata* on
483 fine sands. The presence of *T. muricata* and *V. mirabilis* on the shelf edge (~130 m
484 depth) is rather surprising, as both species have mostly been reported in deeper
485 settings (e.g. Michez et al., 2014). On fine sand floors, large hydrozoans have been
486 occasionally observed, such as *Nemertesia antennina*, *Nemertesia ramosa* or
487 *Lytocarpia myriophyllum*, which co-occurred alongside with *L. phalangium* in
488 agreement with previous observations in the Tyrrhenian Sea (Massi, 2005). However,
489 these hydrozoans present very low abundances in the Menorca Channel

490 (Supplementary material 3), in contrast with dense facies observed in other areas of
491 the Mediterranean Sea (Pérès and Picard, 1964).

492 The brachiopod *Gryphus vitreus* (Fig. 3d) constitutes 81% of all observed
493 organisms in Assemblage C. *G. vitreus* forms beds that sparsely cover (2 ± 3
494 individuals m^{-2} (mean \pm SD)) sandy grounds on and beyond the shelf edge, at 110–
495 330 m depth. This bathymetric distribution contrasts with observations from Corsica
496 and Provence where *G. vitreus* beds reach a maximum depth of 200 m and 250 m,
497 respectively (Emig, 1985; 1987). Conversely, communities dominated by *G. vitreus*
498 have been reported in deeper environments of 660–870 m depth in the Balearic Basin
499 (Cartes et al., 2009). In the upper slope, at 180–200 m depth, *G. vitreus* forms dense
500 aggregations with more than 25 individuals m^{-2} . However, these densities are rather
501 low if compared to those reported from continental slopes exposed to intense bottom
502 currents (600 individuals m^{-2}) (Emig, 1987). In this regard, occurrences and
503 abundances of *G. vitreus* and other brachiopod appear to be directly related to
504 hydrodynamic conditions (Eshleman and Wilkens, 1979; Emig, 1987).
505 In the study area, *G. vitreus* beds (assemblage C) and *L. phalangium* facies
506 (assemblage B) present similar distributions, occasionally co-occurring for tens of
507 meters as previously shown in the Balearic Archipelago (Aguilar et al., 2014).
508 However, while facies of *L. phalangium* (Assemblage B) have been observed on both
509 fine and coarse sands, *G. vitreus* beds (Assemblage C) are basically restricted to
510 coarse sands (Figs. 2 and 4). This substrate segregation responds to the necessity of *G.*
511 *vitreus* to attach to small pebbles or shells on the surface of the sediment (Emig,
512 1987). The composition of accompanying species in coarse sands of assemblage B
513 and C is very similar, with the sea pen *F. quadrangularis*, the polychaete *L.*
514 *conchilega* and the anemones *C. membranaceus* and *A. oligopodus* amongst the most

515 abundant. *A. oligopodus* and *L. conchilega* have often been reported in soft sediments
516 of the shelf edge and continental slope of the Mediterranean Sea (e.g. Pérès and
517 Picard, 1964; Emig, 1997), whereas, in the *G. vitreus* beds of the Menorca Channel,
518 both species occasionally reach high densities (9.5 and 9 individuals m⁻²,
519 respectively), agreeing with previous observations in the Western Mediterranean Sea
520 (Aguilar et al., 2014; Michez et al., 2014). The accompanying species reported in
521 assemblage C differ from those observed in deeper *G. vitreus* beds in the Balearic
522 Basin, which are accompanied by several sponge species and nemerteans (Cartes et
523 al., 2009).

524 The polychaete *Salmacina dysteri* (Fig. 3e) and two unidentified sponges
525 belonging to the genus *Hamacantha* and *Haliclona* (Fig. 3f) characterize the
526 Assemblage D, occurring on coarse sand with scattered cobbles and pebbles, at 95–
527 140 m depth. These three species represent 63% of all observed organisms, and rarely
528 exceed densities of 1.5 individuals m². Despite the mixed substrate where this
529 assemblage has been observed, the vast majority of the organisms are associated with
530 hard substrates (e.g. the sponges *P. compressa*, *A. aaptos* and *Pachastrella monilifera*
531 (26% of observed organisms), and the gorgonians *E. cavolinii* and *Swiftia pallida*
532 (10% of observed organisms)). A similar situation has been identified in sandy
533 bottoms with *Dendrophyllia cornigera* coral rubble, which also present high
534 abundances of organisms associated to hard substrates (Michez et al., 2014).
535 Conversely, coarse sand patches are mainly occupied by echinoids, holothurians and
536 polychaetes (1% of observed organisms). Isolated *L. phalangium* has been
537 occasionally observed as well. The occurrence of Assemblage D in the same transects
538 than Assemblages A and E (Fig. 4) (mainly in the immediate proximities of
539 outcropping rocks and vertical walls on the shelf edge, and in areas of dead maërl

540 rhodolites in the proximities of shelf shoals) suggests that Assemblage D is a
541 transition between assemblages occurring on hard substrates and those located on
542 coarse sand ones.

543 The gorgonians *E. cavolinii* and *Viminella flagellum*, the soft coral *Nidalia*
544 *studerii*, the small solitary coral *Thalamophyllia gasti* and the incrusting sponge
545 *Hamacantha falcula* (Figs. 3g, 3h, 3i, 3j and 3k) characterize (43% of all observed
546 organisms) the sloping rocky substrates (Assemblage E) from the outer continental
547 shelf to the upper slope (95–340 m depth). Despite this wide bathymetric distribution,
548 this coral garden assemblage (*sensu* Stone, 2006; Buhl-Mortensen and Buhl-
549 Mortensen, 2013) mostly occurs on the shelf edge and uppermost slope at 110–190 m
550 depth (72% of observed sampling units), on rocky outcrops and vertical walls near
551 Cap Formentor and at the Menorca canyon head (Fig. 4). Similarly, other coral
552 gardens have also been observed in the proximities of the shelf edge in several
553 locations of the Western Mediterranean Sea (e.g. Bo et al. 2012; Cau et al., 2017).
554 These environments are most likely exposed to regular currents, which may enhance
555 food availability for the large sized passive suspension feeders that characterize this
556 assemblage (Shepard et al., 1974; Balbín et al., 2012). Both the gorgonians *E.*
557 *cavolinii* and *V. flagellum* had previously been reported as dominant species of rocky
558 assemblages on the Mediterranean shelf edge (Bo et al., 2011b; Angiolillo et al.,
559 2014). In the Menorca Channel, both species mostly form mixed assemblages along
560 with other species (Grinyó et al., 2016), but they can punctually form dense
561 monospecific patches of more than 20 colonies m⁻², as also observed in other areas of
562 the Mediterranean Basin (Pedel and Fabri, 2011; Angiolillo et al., 2014). *N. studeri*
563 and *T. gasti* form dense monospecific assemblages (30 colonies m⁻²). *N. studeri*
564 mostly occurs on gently sloping rocky outcrops, whereas *T. gasti* occurs on steeply

565 sloping rocky outcrops. The incrusting sponge *H. falcula* shows low maximum
566 densities of 5 individuals m⁻² but of large size (> 20 cm diameter), covering large
567 areas of the rocky bottom, and perhaps excluding other species (Fig. 3k). Assemblage
568 E is the most diverse of the six megabenthic assemblages identified in the study area.
569 Eighteen species of demosponges have been observed as accompanying species (25%
570 of all observed organisms) mostly as scattered individuals spread throughout the
571 transects (2.4 ± 4 individuals m⁻² (mean \pm SD)), only occasionally reaching high
572 densities (15 individuals m⁻²). Some of these sponges reach large dimensions (> 20
573 cm height and width) such as the massive *Haliclona magna* or the fan shaped
574 *Phakellia robusta*, *P. monilifera* and *P. compressa*. Anthozoans account for 57% of
575 all observed organisms in Assemblage E, with 22 different species. Besides *E.*
576 *cavolinii* and *V. flagellum*, eight gorgonian species have been also observed in this
577 assemblage: *Acanthogorgia hirsuta*, *Bebryce mollis*, *Callogorgia verticillata*,
578 *Corallium rubrum*, *Muriceides lepida*, *Paramuricea clavata*, *P. macrospina*, and *S.*
579 *pallida*. Gorgonians formed multispecific high-density patches (~20 colonies m⁻²)
580 (Grinyó et al., 2016), which contrasts with the lower gorgonian diversity in coastal
581 and bathyal environments of the Mediterranean Sea (e.g. Gori et al., 2011; Cartes et
582 al., 2013). The antipatharians *Antipathella subpinnata*, *Antipathes dichotoma* and
583 *Leiopathes glaberrima* occur in low densities (1–4 colonies m⁻²) in mixed
584 assemblages with gorgonians, as also observed at similar depths in other areas of the
585 Mediterranean Sea (e.g. Bo et al., 2009, 2012; Deidun et al., 2014). Finally, the
586 recently described soft coral *Chironephthya mediterranea* (López-González et al.,
587 2015) and *Paralcyonium spinulosum* are also largely represented in these rocky
588 bottoms. Very similar anthozoan assemblages have also been described at similar
589 depths on rocky substrates in the southern Sardinian shelf edge (Cau et al., 2017). Due

590 to the complex three-dimensional structure they form, and the slow growth of
591 gorgonian and antipatharian species (Sherwood and Edinger, 2009), deep coral
592 gardens are extremely vulnerable to physical damage by fishing, (Angiolillo et al.,
593 2015) and pollution (Silva et al., 2015), displaying extremely slow recovery (Althaus
594 et al., 2009).

595 Finally, vertical rocky substrates at 95–210 m depth are dominated by
596 incrusting sponges (Assemblage F), with an unidentified incrusting sponge of the
597 genus *Rhabderemia* (Fig. 31) accounting for 64% of all observed organisms (max = 23
598 individuals m⁻²), and other incrusting sponges representing 10% of all observed
599 organisms. Incrusting sponges seem to be the only organisms adapted to colonize this
600 environment, alternating with the conversely highly diverse coral gardens
601 (Assemblage E), depending on the substrate slope.

602 Unlike areas of the Gulf of Lion (Pérès and Picard, 1964; Orejas et al., 2009;
603 Gori et al., 2013; Fabri et al., 2014) and the Catalan margin (Lastras et al., 2016), only
604 a few colonies of the cold-water coral *Madrepora oculata* have been observed on
605 vertical rocky walls at 320 m depth in the Menorca Channel. This could suggest that
606 this species might be restricted to deeper environments in the study area (> 350 m
607 depth), as observed in other places of the Mediterranean Basin (e.g. Etiope et al.,
608 2010; Taviani et al., 2015).

609 Benthic communities in the shallow area of the Menorca Channel have been
610 also classified according to the European Nature Information System (EUNIS)
611 (Barberá et al., 2012). Amongst the deeper assemblages described in this study, *L.*
612 *phalangium* beds (Assemblage B) correspond to the EUNIS facies "*L. phalangium* in
613 Mediterranean communities of the shelf-edge detritic bottom" (A5.472), whereas *G.*
614 *vitreus* beds (Assemblage C) correspond to the EUNIS category "Communities of

615 bathyal detritic sands with *G. vitreus*" (A6.31). Conversely, the remaining
616 assemblages characterized in this study do not have a clear correspondence to EUNIS
617 categories. Sponge grounds (Assemblage A) can be only generically classified into
618 the EUNIS "Maërl bed" category (A5.51), whereas the transition assemblage
619 (Assemblage D) could fall within the EUNIS category of "Mosaics of mobile and
620 non-mobile substrata in the circalittoral zone" (X33). Classification into EUNIS
621 categories is more complex for the hard-bottom assemblages described in this study.
622 Coral gardens (Assemblage E) and vertical walls (Assemblage F) would both be
623 classified as EUNIS "Rocky substrates in circalittoral" (A4.2) and "Deep-sea
624 bedrocks" (A6.11). These results highlight the limitations of EUNIS and the need to
625 improve this classification system for Mediterranean benthic environments occurring
626 below 100 m depth.

627 The highest megafaunal species richness and beta-diversity (i.e. species
628 turnover) is observed in the shelf edge (Fig. 6). This pattern probably results from the
629 synergy caused by habitat heterogeneity and hydrodynamic conditions along the shelf
630 edge. Indeed, rocky outcrops and vertical walls alternate with soft sedimented
631 grounds of varying grain sizes over the shelf edge. Moreover, both passive and active
632 suspension feeders may benefit from the stable environmental conditions and
633 hydrodynamic processes that enhance particle suspension in the near-bottom water
634 layers on the shelf edge (Thiem et al., 2006). It has also been suggested that the
635 observed increase in megafauna diversity at intermediate depths may result from the
636 merging of species with shallower and deeper distributions, causing a mid domain
637 effect (Colwell and Lees, 2000) as previously observed for deep coral communities in
638 the north Pacific (Stone, 2006; Matsumoto et al., 2007).

639 Benthic megafauna such as erect and massive sponges (Klitgaard and Tendal,

640 2004), gorgonians (Maynou and Cartes, 2012), antipatharians (Koslow et al., 2001)
641 and crinoids (Smith et al., 2000), are extremely sensitive to bottom trawling fishing.
642 Low trawling pressure at 100–500 m depth in the study area (Fig. 7) and the natural
643 protection offered by rocky escarpments and vertical walls may explain the
644 preservation of the observed high-density and high-diverse megafauna assemblages
645 on the continental shelf edge. Protected bottom trawling on the continental shelf and
646 edge (Watling and Norse, 1998) has probably fragmented megabenthic assemblages
647 (Hall-Spencer et al., 2002), confining them to remote and inaccessible environments
648 (Díaz et al., 2015; Bo et al., 2015). The observed complexity and high-diversity of
649 benthic megafauna in the Menorca Channel, portrays how benthic community may
650 have been in several areas of the Mediterranean continental shelf and shelf edge
651 before the cumulative impact of decades of bottom trawling. Knowledge of the
652 composition and distribution of deep benthic communities represent the
653 indispensable baseline for the establishment of effective management measures for
654 the conservation and recovery of deep ecosystems in large marine protected areas
655 such as the Menorca Channel. Although the establishment of these large protection
656 zones may pose potentially challenging situations amongst stakeholders, economic
657 benefits may eventually materialize, including the recovery of degraded fisheries
658 (Pipitone et al., 2000) and the maintenance of ecosystem services (Balmford et al.,
659 2002).

660

661 **5. Conclusions:**

662

663 - Six megabenthic assemblages are distributed throughout the outermost continental
664 shelf and upper slope of the Menorca Channel, being mainly segregated by substrate

665 type and depth.

666

667 - Beds of the crinoid *Leptometra phalangium* and the brachiopod *Gryphus vitreus*

668 dominate soft substrates.

669

670 - Sponges dominate hard substrates on the outer shelf, whereas gorgonians, corals and

671 incrusting sponges dominate hard substrates on the shelf edge and upper slope.

672

673 - The highest diversity of megabenthic species is found in the shelf edge, within the

674 studied bathymetric range.

675

676 - Trawling pressure concentrates above 100 m depth and below 500 m depth;

677 consequently, low trawling pressure between 100 and 500 m depth probably

678 contributes to the preservation of the observed benthic assemblages.

679

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681

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692

693 **References**

694

695 Abella, A., Serena, F., Ria, M., 2005. Distributional response to variations in
696 abundance over spatial and temporal scales for juveniles of European hake
697 (*Merluccius merluccius*) in the Western Mediterranean Sea. Fisheries Research
698 71, 295–310. doi:10.1016/j.fishres.2004.08.036

699

700 Acosta, J., Canals, M., López-Martínez, J., Muñoz, A., Herranz, P., Urgeles, R.,
701 Palomo, C., Casamor, J.L., 2002. The Balearic Promontory geomorphology
702 (western Mediterranean): Morphostructure and active processes. Geomorphology
703 49, 177–204. doi:10.1016/S0169-555X(02)00168-X

704

705 Aguilar, R., Serrano, A., García, S., Alvarez, H., Blanco, J., López, J., Marín P.,
706 Pastor, X., 2014. Vulnerable habitats and species in the deep-sea Emile Baudot
707 escarpment (South Balearic Islands) Surveyed by ROV. In Proceedings of the 1st
708 Mediterranean symposium on the conservation of Dark Habitats. Pargent-Martini
709 and M. Bricchet, (Eds.), RAC/SPA Publ. Tunis. 2014

710

711 Althaus, F., Williams, A., Schlacher, T.A., Kloser, R.J., Green, M.A., Barker, B.A.,
712 Bax, N.J., Brodie, P., Schlacher-Hoenlinger, M.A., 2009. Impacts of bottom
713 trawling on deep-coral ecosystems of seamounts are long-lasting. Marine
714 Ecology Progress Series 397, 279–294. doi:10.3354/meps08248

715

716 Ambroso, S., Gori, A., Dominguez-Carrió, C., Gili, J.M., Berganzo, E., Teixidó, N.,
717 Greenacre, M., Rossi, S., 2013. Spatial distribution patterns of the soft corals
718 *Alcyonium acaule* and *Alcyonium palmatum* in coastal bottoms (Cap de Creus,
719 northwestern Mediterranean Sea). Marine Biology 160, 3059–3070.
720 doi:10.1007/s00227-013-2295-4

721

722 Angiolillo, M., Bavestrello, G., Bo, M., Cau, A, Cau, A., Giusti, M., Salvati, E.,
723 Tunesi, L., Canese, S., 2014. Distribution of the deep-dwelling gorgonian
724 *Viminella flagellum* in the Italian Western Mediterranean Sea by means of multi-
725 year ROV survey 2013-2014. In: 1st Mediterranean Symposium on the
726 conservation of Dark Habitats, Portoroz, Slovenia 31 October 2014.

727

728 Angiolillo, M., di Lorenzo, B., Farcomeni, A., Bo, M., Bavestrello, G., Santangelo,
729 G., Cau, A., Mastascusa, V., Cau, A., Sacco, F., Canese, S., 2015. Distribution
730 and assessment of marine debris in the deep Tyrrhenian Sea (NW Mediterranean
731 Sea, Italy). Marine Pollution Bulletin 92, 149–159.
732 doi:10.1016/j.marpolbul.2014.12.044

733

734 Aschan, M., Fossheim, M., Greenacre, M., Primicerio, R., 2013. Change in Fish

735 Community Structure in the Barents Sea. PLoS One 8, 1–12.
736 doi:10.1371/journal.pone.0062748
737

738 Balbín, R., Flexas, M.M., López-Jurado, J.L., Peña, M., Amores, A., Alemany, F.,
739 2012. Vertical velocities and biological consequences at a front detected at the
740 balearic sea. Continental Shelf Research 47, 28–41.
741 doi:10.1016/j.csr.2012.06.008
742

743 Balmford A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins,
744 M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S.,
745 Paavola, J., Matthew, R., Rosendo, S., Roughgarden, J., Trumper, K., Turner,
746 R.K., 2002. Economic Reasons for Conserving Wild Nature. Science 297, 950–
747 953. doi:10.1126/science.1073947
748

749 Barberá, C., Moranta, J., Ordines, F., Ramón, M., Mesa, A., Díaz-Valdés, M., Grau,
750 A.M., Massutí, E., 2012. Biodiversity and habitat mapping of Menorca Channel
751 (western Mediterranean): implications for conservation. Biodiversity and
752 Conservation 21, 701–728. doi:10.1007/s10531-011-0210-1
753

754 Beazley, L., Kenchington, E., Yashayaev, I., Murillo, F.J., 2015. Drivers of epibenthic
755 megafaunal composition in the sponge grounds of the Sackville Spur, northwest
756 Atlantic. Deep Sea Research Part I: Oceanographic Research Papers 98, 102–
757 114. doi:10.1016/j.dsr.2014.11.016
758

759 Bennecke, S., Metaxas, A., 2016. Effectiveness of a deep-water coral conservation
760 area: evaluation of its boundaries and changes in octocoral communities over 13
761 years. Deep Sea Research Part II: Topical Studies in Oceanography In press.
762 doi:10.1016/j.dsr2.2016.06.005
763

764 Bertolino, M., Bo, M., Canese, S., Bavestrello, G., Pansini, M., 2015. Deep sponge
765 communities of the Gulf of St Eufemia (Calabria, southern Tyrrhenian Sea), with
766 description of two new species. Journal of the Marine Biological Association of
767 the United Kingdom 95, 1371–1387.
768

769 Bertolino, M., Bo, M., Canese, S., Bavestrello, G., Pansini, M., 2013. Deep sponge
770 communities of the Gulf of St Eufemia (Calabria, southern Tyrrhenian Sea), with
771 description of two new species. Journal of the Marine Biological Association fo
772 the United Kingdom 95, 1371–1387. doi:10.1017/S0025315413001380
773

774 Bo, M., Bavestrello, G., Angiolillo, M., Calcagnile, L., Canese, S., Cannas, R., Cau,
775 A., Elia, M.D., Oriano, F.D., Follesa, M.C., Quarta, G., Cau, A., 2015.
776 Persistence of Pristine Deep-Sea Coral Gardens in the Mediterranean Sea (SW
777 Sardinia). PLoS One 1–21. doi:10.1371/journal.pone.0119393
778

779 Bo, M., Canese, S., Bavestrello, G., 2013. Discovering Mediterranean black coral
780 forests: *Parantipathes larix* (Anthozoa: Hexacorallia) in the Tuscan Archipelago,
781 Italy. Italian Journal of Zoology 81, 112–125.
782 doi:10.1080/11250003.2013.859750
783

784 Bo, M., Canese, S., Spaggiari, C., Pusceddu, A., Bertolino, M., Angiolillo, M., Giusti,

785 M., Loreto, M.F., Salvati, E., Greco, S., Bavestrello, G., 2012. Deep Coral Oases
786 in the South Tyrrhenian Sea. PLoS One 7. doi:10.1371/journal.pone.0049870
787

788 Bo, M., Bertolino, M., Bavestrello, G., Canese, S., Giusti, M., Angiolillo, M., Pansini,
789 M., Taviani, M., 2011a. Role of deep sponge grounds in the Mediterranean Sea:
790 a case study in southern Italy. Hydrobiologia 687, 163–177. doi:10.1007/s10750-
791 011-0964-1
792

793 Bo, M., Bavestrello, G., Canese, S., Giusti, M., Angiolillo, M., Cerrano, C., Salvati,
794 E., Greco, S., 2011b. Coral assemblage off the Calabrian Coast (South Italy)
795 with new observations on living colonies of *Antipathes dichotoma*. Italian
796 Journal of Zoology 78, 231–242. doi:10.1080/11250001003652619
797

798 Bo, M., Di CaMillo, C.G., Bertolino, M., Povero, P., Misic, C., Castellano, M.,
799 Covazzi Harriague, A., Gasparini, G.P., Borghini, M., Schroeder, K., Bavestrello,
800 G., 2010. The megabenthic assemblages of the Verdelli Seamount (North
801 Tyrrhenian Sea). Biologia Marina Mediterranea 17, 94-97.
802

803 Bo, M., Bavestrello, G., Canese, S., Giusti, M., Salvati, E., Angiolillo, M., Greco, S.,
804 2009. Characteristics of a black coral meadow in the twilight zone of the central
805 Mediterranean Sea. Marine Ecology Progress Series 397, 53–61.
806 doi:10.3354/meps08185
807

808 Buhl-Mortensen, L., Serigstad, B., Buhl-Mortensen, P., Olsen, M.N., Ostrowski, M.,
809 Błażewicz-Paszkowycz, M., Appoh, E., 2016. First observations of the structure
810 and megafaunal community of a large Lophelia reef on the Ivorian-Ghanaian
811 margin (the Gulf of Guinea). Deep Sea Res. Part II: Topical Studies in
812 Oceanography In press, doi:10.1016/j.dsr2.2016.06.007
813

814 Buhl-Mortensen, P., Buhl-Mortensen, L., 2013. Diverse and vulnerable deep-water
815 biotopes in the Hardangerfjord. Marine Biology Research 10, 253–267.
816 doi:10.1080/17451000.2013.810759
817

818 Cartes, J.E., Lo Iacono, C., Mamouridis, V., López-Pérez, C., Rodríguez, P., 2013.
819 Geomorphological, trophic and human influences on the bamboo coral *Isidella*
820 *elongata* assemblages in the deep Mediterranean: To what extent does *Isidella*
821 form habitat for fish and invertebrates? Deep Sea Research Part I: Oceanography
822 Research Paper 76, 52–65. doi:10.1016/j.dsr.2013.01.006
823

824 Cartes, J.E., Maynou, F., Fanelli, E., Romano, C., Mamouridis, V., Papiol, V., 2009.
825 The distribution of megabenthic, invertebrate epifauna in the Balearic Basin
826 (western Mediterranean) between 400 and 2300 m: Environmental gradients
827 influencing assemblages composition and biomass trends. Journal of Sea
828 Research 61, 244–257.
829

830 Cau, A., Moccia, D., Follesa, M.C., Alvito, A., Canese, S., Angiolillo, M., Cuccu, D.,
831 Bo, M., Cannas, R., 2017. Coral forests diversity in the outer shelf of the south
832 Sardinian continental margin. Deep Sea Research Part I, *in press*
833
834

835 Clark, M.R., Althaus, F., Schlacher, T.A., Williams, A., Bowden, D.A., Rowden,
836 A.A., 2016. The impacts of deep-sea fisheries on benthic communities: A
837 review. *ICES Journal of Marine Science* 73, 51–69. doi:10.1093/icesjms/fsv123
838

839 Colloca, F., Cardinale, M., Belluscio, A., Ardizzone, G., 2003. Pattern of distribution
840 and diversity of demersal assemblages in the central Mediterranean sea.
841 *Estuarine Coastal Shelf Science* 56, 469–480. doi:10.1016/S0272-
842 7714(02)00196-8
843

844 Colloca, F., Carpentieri, P., Balestri, E., Ardizzone, G.D., 2004. A critical habitat for
845 Mediterranean fish resources: shelf-break areas with *Leptometra phalangium*
846 (Echinodermata: Crinoidea). *Marine Biology* 145, 1129–1142.
847 doi:10.1007/s00227-004-1405-8
848

849 Colwell, R.K., Lees, D.C., 2000. The mid-domain effect: Geometric constraints on
850 the geography of species richness. *Trends in Ecology and Evolution* 15, 70–76.
851 doi:10.1016/S0169-5347(99)01767-X
852

853 Coppari, M., Gori, A., Viladrich, N., Saponari, L., Canepa, A., Grinyó, J., Olariaga,
854 A., Rossi, S., 2016. The role of Mediterranean sponges in benthic-pelagic
855 coupling processes: *Aplysina aerophoba* and *Axinella polypoides* case studies.
856 *Journal of Experimental Marine Biology and Ecology* 477, 57–68.
857

858 Deidun, A., Andaloro, F., Bavestrello, G., Canese, S., Consoli, P., Micallef, A.,
859 Romeo, T., Bo, M., 2014. First characterisation of a *Leiopathes glaberrima*
860 (Cnidaria: Anthozoa: Antipatharia) forest in Maltese exploited fishing grounds.
861 *Italian Journal of Zoology* 82, 37–41. doi:10.1080/11250003.2014.986544
862

863 De Leo, F.C., Vetter, E.W., Smith, C.R., Rowden, A.A., McGranaghan, M., 2014.
864 Spatial scale-dependent habitat heterogeneity influences submarine canyon
865 macrofaunal abundance and diversity off the Main and Northwest Hawaiian
866 Islands. *Deep Sea Res. Part II* 104, 267–290.
867

868 Díaz, D., Bo, M., Gaamour, A., Ambroso, S., Bavestrello, G., Bed Abdallah, L., Ben
869 Salem, S., Benmassaoued, R., Canese, S., Cerasi, S., Cherif, M., Djabou, H.,
870 Dominguez-Carrió, C., Goñi, R., Grinyó, J., Gutiérrez, V., Jaziri, S., Khemiri,
871 S., Koched, W., Nurus, P., Mallol, S., Misaoui, H., Ben Amor, M.M., Muñoz,
872 A., Palomeque, R., Profeta, A., Rjeibi, O., Santín, A., Gili, J.M., 2015. Towards
873 Ecosystem Conservation and sustainable artisanal fisheries in the Mediterranean
874 basin. In: *ICES Annual Science Conference 2015*. Copenhagen, Denmark. ICES
875 CM 2015/F:23.
876

877 Emig, C.C., 1997. Bathyal zones of the Mediterranean continental slope: an attempt.
878 *Publicación Especiecial Instituto Español Oceanografía* 23, 23–33.
879

880 Emig, C.C., 1987. Offshore brachiopods investigated by submersible. *Journal of*
881 *Experimental Marine Biology and Ecology* 108, 261–273.
882

883 Emig, C.C., 1985. Distribution et synécologie des fonds à *Gryphus vitreus*
884 (Brachiopoda) en Corse. *Marine Biology* 90, 139–146 (1985).

885
886 Eshleman, W.P., Wilkens, J.L., 1979. Brachiopod orientation to current direction and
887 substrate position (*Terebratalia transversa*). Canadian Journal of Zoology 57,
888 2079–2082. doi:10.1139/z79-274
889
890 Etiope, G., Savini, A., Lo Bue, N., Favali, P., Corselli, C., 2010. Deep-sea survey for
891 the detection of methane at the “Santa Maria di Leuca” cold-water coral mounds
892 (Ionian Sea, South Italy). Deep Research Part II: Topical Studies in
893 Oceanography 57, 431–440. doi:10.1016/j.dsr2.2009.08.020
894
895 Fabri, M., Pedel, L., Beuck, L., Galgani, F., Hebbeln, D., Freiwald, A., 2014.
896 Megafauna of vulnerable marine ecosystems in French mediterranean submarine
897 canyons: Spatial distribution and anthropogenic impacts. Deep Sea Research Part
898 II: Topical Studies in Oceanography 104, 184–207.
899 doi:10.1016/j.dsr2.2013.06.016
900
901 Fosså, Jan Helge, Mortensen, P.B, Furevik, D.M., 2002. The deep-water coral
902 *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts.
903 Hydrobiologia 471, 1–12. doi:10.1023/A:1016504430684
904
905 Fredj, G., 1964. Contributions à l’étude bionomique de la Méditerranée occidentale
906 (Cote du Var et des Alpes maritimes-cote occidentale de Corse). Fascicule 2: La
907 région de Saint-Tropez: du cap Taillat au cap de Saint-Tropez (région A 1).
908 Bulletin Institut Oceanografic de Monaco, 63 1-55. 63.
909
910 García, A., Alemany, F., Velez-Belchí, P., López Jurado, J.L., Cortés, D., de la Serna,
911 J.M., González Pola, C., Rodriguez, J.M., Jnasá, J., Ramírez, T., 2005.
912 Characterization of the bluefin tuna spawning habitat off the Balearic
913 Archipelago in relation to key hydrographic features and associated
914 environmental conditions. Collected Volume of Scientific Papers ICCAT 58,
915 535–549.
916
917 Getis, A., Keith Ord, J.K., 1996. Local spatial statistics: an overview. Spatial analysis:
918 modelling in a GIS environment 374.
919
920 Gori, A., Rossi, S., Berganzo, E., Pretus, J.L., Dale, M.R.T., Gili, J.M., 2011. Spatial
921 distribution patterns of the gorgonians *Eunicella singularis*, *Paramuricea clavata*
922 and *Leptogorgia sarmentosa* (Cap of Creus, Northwestern Mediterranean Sea).
923 Marine Biology 158, 143–158.
924
925 Gori, A., Orejas, C., Madurell, T., Bramanti, L., Martins, M., Quintanilla, E., Marti-
926 Puig, P., Lo Iacono, C., Puig, P., Requena, S., Greenacre, M., Gili, J.M., 2013.
927 Bathymetrical distribution and size structure of cold-water coral populations in
928 the Cap de Creus and Lacaze-Duthiers canyons (northwestern Mediterranean).
929 Biogeosciences 10, 2049–2060. doi:10.5194/bg-10-2049-2013
930
931 Gotelli, N.J., Colwell, R.K., 2001. Quantifying biodiversity: procedures and pitfalls in
932 the measurement and comparison of species richness. Ecology Letters 4, 379–
933 391.
934

- 935 Greenacre, M., Primicerio, R., 2013. Chapter 13. Correspondence Analysis, in:
936 Multivariate Analysis of Ecological Data. p. 177.
937 doi:10.1177/0049124106290316
938
- 939 Grinyó, J., Gori, A., Ambroso, S., Purroy, A., Calatayud, C., Dominguez-Carrió, C.,
940 Coppari, M., Lo Iacono, C., López-González, P.J., Gili, J.M., 2016. Diversity,
941 distribution and population size structure of deep Mediterranean gorgonian
942 assemblages (Menorca Channel, Western Mediterranean Sea). *Progress in*
943 *Oceanography* 145, 42–56. doi:10.1016/j.pocean.2016.05.001
944
- 945 Hall-Spencer, J., Allain, V., Fosså, J.H., Copernic, P.N., 2002. Trawling damage to
946 Northeast Atlantic ancient coral reefs. *Proceedings of the Royal Society of*
947 *London B: Biological Sciences* 269, 507–511. doi:10.1098/rspb.2001.1910
948
- 949 Hintzen, N.T., Piet, G.J., Brunel, T., 2010. Improved estimation of trawling tracks
950 using cubic Hermite spline interpolation of position registration data. *Fisheries*
951 *Research* 101, 108–115. doi:10.1016/j.fishres.2009.09.014
952
- 953 Howell, K.-L., Piechaud, N., Downie, A.-L., Kenny, A., 2016. The distribution of
954 deep-sea sponge aggregations in the North Atlantic and implications for their
955 effective spatial management. *Deep Sea Research Part I: Oceanographic*
956 *Research Paper* 115, 309–320. doi:10.1016/j.dsr.2016.07.005
957
- 958 Huvenne, V.A.I., Bett, B.J., Masson, D.G., Le Bas, T.P., Wheeler, A.J., 2016.
959 Effectiveness of a deep-sea cold-water coral Marine Protected Area, following
960 eight years of fisheries closure. *Biological Conservation* 200, 60–69.
961 doi:10.1016/j.biocon.2016.05.030
962
- 963 Joher, S., Ballesteros, E., Cebrian, E., Sánchez, N., Rodríguez-Prieto, C., 2012. Deep-
964 water macroalgal-dominated coastal detritic assemblages on the continental shelf
965 off Mallorca and Menorca (Balearic Islands, Western Mediterranean). *Botanica*
966 *Marina* 55, 485–497. doi:10.1515/bot-2012-0113
967
- 968 Kallianiotis, A., Sophronidis, K., Vidoris, P., Tselepides, A., 2000. Demersal fish and
969 megafaunal assemblages on the Cretan continental shelf and slope (NE
970 Mediterranean): Seasonal variation in species density, biomass and diversity.
971 *Progress in Oceanography* 46, 429–455. doi:10.1016/S0079-6611(00)00028-8
972
- 973 Klitgaard, A.B., Tendal, O.S., 2004. Distribution and species composition of mass
974 occurrences of large-sized sponges in the northeast Atlantic. *Progress in*
975 *Oceanography* 61, 57–98. doi:10.1016/j.pocean.2004.06.002
976
- 977 Koslow, J.A., Gowlett-Holmes, K., Lowry, J.A., O’Hara, T., Poore, G.C.B., Williams,
978 A., 2001. Seamount Benthic Macrofauna off Southern Tasmania: Community
979 Structure and Impacts of Trawling. *Marine Ecology Progress Series* 213, 111–
980 125. doi:10.3354/meps213111
981
- 982 Kutti, T., Bannister, R.J., Fosså, J.H., 2013. Community structure and ecological
983 function of deep-water sponge grounds in the Traenadypet MPA-Northern
984 Norwegian continental shelf. *Continental Shelf Research* 69, 21–30.

- 985 doi:10.1016/j.csr.2013.09.011
986
- 987 Lastras, G., Canals, M., Ballesteros, E., Gili, J.-M., Sanchez-Vidal, A., 2016. Cold-
988 Water Corals and Anthropogenic Impacts in La Fonera Submarine Canyon Head,
989 Northwestern Mediterranean Sea. PLoS One 11, e0155729.
990 doi:10.1371/journal.pone.0155729
991
- 992 Lavaleye, M.S.S., Duineveld, G.C.A., Berghuis, E.M., Kok, A., Witbaard, R., 2002.
993 A comparison between the megafauna communities on the N. W. Iberian and
994 Celtic continental margins—effects of coastal upwelling? Progress in
995 Oceanography 52, 459–476.
996
- 997 Lee, J., South, A.B., Jennings, S., 2010. Developing reliable, repeatable, and
998 accessible methods to provide high-resolution estimates of fishing-effort
999 distributions from vessel monitoring system (VMS) data. ICES Journal of
1000 Marine Science 67, 1260–1271. doi:10.1093/icesjms/fsq010
1001
- 1002 López-González, P.J., Grinyó, J., Gili, J.M., 2015. *Chironephthya mediterranea* n. sp.
1003 (Octocorallia, Alcyonacea, Nidaliidae), the first species of the genus discovered
1004 in the Mediterranean Sea. Marine Biodiversity 45, 667–688.
1005 doi:10.1007/s12526-014-0269-5
1006
- 1007 Maldonado, M., Aguilar, R., Bannister, R.J., James, J., Conway, K.W., Dayton, P.K.,
1008 Cristina, D., Gutt, J., Kelly, M., Kenchington, E.L.R., Leys, S.P., Shirley, A.,
1009 Tendal, O.S., Rapp, H.T., Klaus, R., Young, C.M., 2016. Sponge Grounds as
1010 Key Marine Habitats: A Synthetic Review of Types, Structure, Functional roles
1011 and Conservation Concerns, in: Animal Forest. pp. 3–39. doi:10.1007/978-3-
1012 319-17001-5
1013
- 1014 Mangano, M.C., Porporato, F., De Domenico, F., Profeta, A., Busalacchi, B., 2010.
1015 *Leptometra phalangium* (J. Müller, 1841) Fields from the Southern Tyrrhenian
1016 Sea: Preliminary Data on the Associated Fauna. Biologia Marina Mediterranea
1017 17, 304–305.
1018
- 1019 Massi, D., 2005. Composizione dello "sporco"(macrobenthos non commerciale) della
1020 pesca a strascico Campagna GRUND 2004-Stretto di Sicilia.
1021
- 1022 Mastrototaro, F., D'Onghia, G., Corriero, G., Matarrese, A., Maiorano, P., Panetta, P.,
1023 Gherardi, M., Longo, C., Rosso, A., Sciuto, F., Sanfilippo, R., Gravili, C.,
1024 Boero, F., Taviani, M., Tursi, A., 2010. Biodiversity of the white coral bank off
1025 Cape Santa Maria di Leuca (Mediterranean Sea): An update. Deep Sea Research
1026 Part II: Topical Studies in Oceanography 57, 412–430.
1027 doi:10.1016/j.dsr2.2009.08.021
1028
- 1029 Matsumoto, A.K., Iwase, F., Imahara, Y., Namikawa, H., 2007. Bathymetric
1030 distribution and biodiversity of cold-water octocorals (Coelenterata:
1031 Octocorallia) in Sagami Bay and adjacent waters of Japanese Bulletin of Marine
1032 Science 81, 231–251.
1033
- 1034 Maynou, F., Cartes, J.E., 2012. Effects of trawling on fish and invertebrates from

1035 deep-sea coral facies of *Isidella elongata* in the western Mediterranean. Journal
1036 of the Marine Biological Association of the United Kingdom 92, 1501–1507.
1037 doi:10.1017/S0025315411001603
1038

1039 Michez N., Fourt M., Aish A., Bellan G., Bellan-Santini D., Chevaldonné P., Fabri
1040 M.-C., Goujard A., Harmelin J.-G., Labrune C., Pergent G., Sartoretto S.,
1041 Vacelet J., Verlaque M., 2014. Typologie des biocénoses benthiques de
1042 Méditerranée Version 2. Rapport SPN 2014 - 33, MNHN, Paris, 26 pages.
1043

1044 Millot, C., 1987. Circulation in the western Mediterranean-sea. Oceanological Acta
1045 10, 143–149. doi:10.1016/S0924-7963(98)00078-5
1046

1047 Mytilineou, C., Smith, C.J., Anastasopoulou, A., Papadopoulou, K.N., Christidis, G.,
1048 Bekas, P., Kavadas, S., Dokos, J., 2014. New cold-water coral occurrences in the
1049 Eastern Ionian Sea: Results from experimental long line fishing. Deep Sea
1050 Research Part II: Topical Studies in Oceanography 99, 146–157.
1051 doi:10.1016/j.dsr2.2013.07.007
1052

1053 Oksanen, J., Blanchet, F.G., Friendly M., Kindt, R., Legendre, P., McGlinn, D.,
1054 Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, H.H., Szoecs,
1055 E., Wagner, H., 2015. Vegan: community ecology package. R-package version.
1056

1057 Orejas, C., Gori, A., Lo Iacono, C., Puig, P., Gili, J., Dale, M., 2009. Cold-water
1058 corals in the Cap de Creus canyon, northwestern Mediterranean: spatial
1059 distribution, density and anthropogenic impact. Marine Ecology Progress Series
1060 397, 37–51. doi:10.3354/meps08314
1061

1062 Pedel. L., Fabri, M.C., 2011. Description et cartographie des biocénoses benthiques
1063 rencontrées au cours de la campagne MEDSEACAN (Aamp/Comex).
1064

1065 Pérès, J.M., Picard, J., 1964. Nouveau Manuel de Bionomie benthique de la Mer
1066 Méditerranée. Station Marine d'Endoume.
1067

1068 Pérès, J., 1967. The Mediterranean benthos. Oceanography and Marine Biology: an
1069 Annual Review 5, 449–533.
1070

1071 Piet, G.J., Quirijns, F.J., 2009. The importance of scale for fishing impact estimations.
1072 Canadian Journal of Fisheries and Aquatic Sciences 66, 829–835.
1073 doi:10.1139/F09-042
1074

1075 Pipitone, C., Badalamenti, F., D'Anna, G., Patti, B., 2000. Fish biomass increase after
1076 a four-year trawl ban in the Gulf of Castellammare (NW Sicily, Mediterranean
1077 Sea). Fisheries Research 48, 23–30. doi:10.1016/S0165-7836(00)00114-4
1078

1079 Porteiro, F.M., Gomes-Pereira, J.N., Pham, C.K., Tempera, F., Santos, R.S., 2013.
1080 Distribution and habitat association of benthic fish on the Condor seamount (NE
1081 Atlantic, Azores) from in situ observations. Deep Sea Research Part II: Topical
1082 Studies in Oceanography 98, 114–128. doi:10.1016/j.dsr2.2013.09.015
1083

1084 R Core Team, 2014. R: A language and environment for statistical computing. R

1085 Foundation for Statistical Computing, Vienna, Austria. URL
1086 <http://www.R-project.org>.

1087 Rice, A.L.; Turston, M.H.; New, A.L., 1990. Dense aggregations of a hexactinellid
1088 sponge, in the Porcupine Seabight (northeast Atlantic Ocean) and possible
1089 causes. *Progress in Oceanography* 24, 179–196.

1090
1091 Ruiz, S., Pascual, A., Garau, B., Faugère, Y., Alvarez, A., Tintoré, J., 2009.
1092 Mesoscale dynamics of the Balearic Front, integrating glider, ship and satellite
1093 data. *Journal of Marine Systems* 78, S3–S16. doi:10.1016/j.jmarsys.2009.01.007
1094

1095 Sacchi, J., 2008. The use of trawling nets in the Mediterranean. Problems and
1096 selectivity options. *Options Méditerranéennes. Série b: Etudes et Recherches* 62,
1097 87–96.

1098
1099 Sampaio, Í., Braga-Henriques, A., Pham, C., Ocaña, O., de Matos, V., Morato, T.,
1100 Porteiro, F.M., 2012. Cold-water corals landed by bottom longline fisheries in
1101 the Azores (north-eastern Atlantic). *Journal of the Marine Biological Association*
1102 of the United Kingdom 92, 1547–1555. doi:10.1017/S0025315412000045
1103

1104 Seike, K., Shirai, K., Kogure, Y., 2013. Disturbance of Shallow Marine Soft-Bottom
1105 Environments and Megabenthos Assemblages by a Huge Tsunami Induced by
1106 the 2011 M9.0 Tohoku-Oki Earthquake. *PLoS One* e65417.

1107
1108 Shepard, F.P., Marshall, N.F., McLoughlin, P.A., 1974. Currents in submarine
1109 canyons. *Deep Sea Research and Oceanographic Abstracts* 21, 691–706.
1110 doi:10.1016/0011-7471(74)90077-1
1111

1112 Sheppard, C.R.C., Ateweberhan, M., Bowen, B.W., Carr, P., Chen, C.A., Clubbe, C.,
1113 Craig, M.T., Ebinghaus, R., Eble, J., Fitzsimmons, N., Gaither, M.R., Gan, C.H.,
1114 Gollock, M., Guzman, N., Graham, N.A.J., Harris, A., Jones, R., Keshavmurthy,
1115 S., Koldewey, H., Lundin, C.G., Mortimer, J.A., Obura, D., Pfeiffer, M., Price,
1116 A.R.G., Purkis, S., Raines, P., Readman, J.W., Riegl, B., Rogers, A., Schleyer,
1117 M., Seaward, M.R.D., Sheppard, A.L.S., Tamelander, J., Turner, J.R., Visram,
1118 S., Vogler, C., Vogt, S., Wolschke, H., Yang, J.M.C., Yang, S.Y., Yesson, C.,
1119 2012. Reefs and islands of the Chagos Archipelago, Indian Ocean: Why it is the
1120 world's largest no-take marine protected area. *Aquatic Conservation: Marine and*
1121 *Freshwater Ecosystems* 22, 232–261. doi:10.1002/aqc.1248
1122

1123 Sherwood, O.A., Edinger, E.N., 2009. Ages and growth rates of some deep-sea
1124 gorgonian and antipatharian corals of Newfoundland and Labrador. *Canadian*
1125 *Journal of Fisheries and Aquatic Science* 66, 142–152. doi:10.1139/F08-195
1126

1127 Silva, M., Etnoyer, P.J., MacDonald, I.R., 2015. Coral injuries observed at
1128 mesophotic Reefs after the Deepwater Horizon oil discharge. *Deep Sea Research*
1129 *Part II Topical Studies in Oceanography* 129, 96–107.
1130 doi:10.1016/j.dsr2.2015.05.013
1131

1132 Smith, C.J., Papadopoulou, K.N., Diliberto, S., 2000. Impact of otter trawling on an
1133 eastern Mediterranean commercial trawl fishing ground. *ICES Journal of Marine*

- 1134 Sciences 57, 1340–1351. doi:10.1006/jmsc.2000.0927
1135
- 1136 Spalding, M.D., Meliane, I., Milam, A., Fitzgerald, F., Hale, L.Z., 2013. Protecting
1137 marine spaces: global targets and changing approaches. *Ocean Yearbook* 27,
1138 213–248.
1139
- 1140 Stone, R.P., 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution,
1141 fine-scale species associations, and fisheries interactions. *Coral Reefs* 25, 229–
1142 238. doi:10.1007/s00338-006-0091-z
1143
- 1144 Taviani, M., Angeletti, L., Canese, S., Cannas, R., Cardone, F., Cau, A., Cau, A.B.,
1145 Follesa, M.C., Marchese, F., Montagna, P., Tessarolo, C., 2015. The “Sardinian
1146 cold-water coral province” in the context of the Mediterranean coral ecosystems.
1147 *Deep Sea Research Part II: Topical Studies in Oceanography* In press.
1148 doi:10.1016/j.dsr2.2015.12.008
1149
- 1150 Ter Braak, C.J.F., 1986. Canonical correspondence analysis: a new eigenvector-
1151 technique for multivariate direct gradient analysis. *Ecology* 67, 1167–1179.
1152
- 1153 Thiem, Ø., Ravagnan, E., Fosså, J.H., Berntsen, J., 2006. Food supply mechanisms
1154 for cold-water corals along a continental shelf edge. *Journal of Marine Systems*
1155 60, 207–219. doi:10.1016/j.jmarsys.2005.12.004
1156
- 1157 Vetter, E.W., Smith, C.R., De Leo, F.C., 2010. Hawaiian hotspots: enhanced
1158 megafaunal abundance and diversity in submarine canyons on the oceanic
1159 islands of Hawaii. *Marine Ecology* 31, 183–199.
1160
- 1161 Watling, L., Norse, E.A., 1998. Disturbance of the Seabed by Mobile Fishing Gear: A
1162 Comparison to Forest Clearcutting. *Conservation Biology* 12, 1180–1197.
1163 doi:10.1046/j.1523-1739.1998.0120061180.x
1164
- 1165 Weinberg, S., 1978. Mediterranean octocorallian communities and the abiotic
1166 environment. *Marine Biology* 49, 41–57.
1167
- 1168 Williams, A., Schlacher, T.A., Rowden, A.A., Althaus, F., Clark, M.R., Bowden,
1169 D.A., Stewart, R., Bax, N.J., Consalvey, M., Kloser, R.J., 2010. Seamount
1170 megabenthic assemblages fail to recover from trawling impacts. *Marine Ecology*
1171 31, 183–199. doi:10.1111/j.1439-0485.2010.00385.x
1172
- 1173 Würtz, M., 2012. *Mediterranean Submarine Canyons: Ecology and Governance*.
1174 International Union for the Conservation of Nature, Gland, Switzerland and
1175 Malaga, Spain.
1176
- 1177
- 1178
- 1179 Figure Legends of Figures larger than 10 M:

1180

1181 **Fig. 3** Most contributing species to the CCA a) *Haliclona* cf. *elegans*, b) *Aplysina cavernicola*, c)
1182 *Leptometra phalangium*, d) *Gryphus vitreus*, e) *Salmacina dysteri*, f) *Hamacantha* sp. 2 (white circle)
1183 and *Haliclona* sp. 1 (black circle), g) *Eunicella cavolinii*, h) *Viminella flagellum* i) *Nidalia studeri*, j)
1184 *Thalamophyllia gasti*, k) *Hamacantha falcula*, l) *Rhabderemia* sp. Scale Bar: 5 cm.

1185

1186 Supplementary material captions:

1187

1188 Supplementary material 1: Transect location, length, depth (minimum and maximum depth), main
1189 substrate (> 50% coverage of sampling units) (M: maërl, CBP: cobbles and pebbles, MS: medium
1190 sands, FS: fine sands, R: rocky substrates), main slope (> 50% coverage of sampling units)(H:
1191 horizontal, S: slopping, V: vertical).

1192

1193 Supplementary material 2: Variation in the resolution of the canonical correspondence analysis (CCA)
1194 ordination biplots when using different sampling unit sizes. Sampling units are colored according to the
1195 dominant substrate: fine sands (yellow), medium sands to gravels (green), cobbles and pebbles
1196 (orange), maërl (blue), outcropping rock (red).

1197

1198 Supplementary material 3: Megabenthic species abundance, mean and maximum density, bathymetric
1199 distribution, and assemblage occurrence.

1200

1201 Supplementary material 4: Multispecific demosponge assemblage (pink sponge = *Haliclona* cf.
1202 *elegans*, bright yellow sponges = *Aplysina cavernicola*) on maërl beds located on the continental shelf
1203 at 99 m depth (transect 22 on Fig. 1).

1204

1205 Supplementary material 5: *Leptometra phalangium* bed at the shelf edge at 130 m depth (transect 44 on
1206 Fig. 1).

1207

1208 Supplementary material 6: *Gryphus vitreus* bed at the upper slope at 200 m depth (transect 27 on Fig.
1209 1).

1210

1211 Supplementary material 7: Cobble grounds with few large demosponges at 130 m depth (transect 30 on
1212 Fig. 1).

1213

1214 Supplementary material 8: Multispecific coral garden (white gorgonian = *Eunicella cavolinii*, yellow
1215 gorgonian = *Acanthogorgia hirsuta*, white tubular sponge = *Haliclona magna*) at the shelf edge 150 m
1216 depth (transect 3 on Fig. 1).

1217

1218 Supplementary material 9: Vertical wall densely colonized by the encrusting sponge *Rhabderemia* sp.
1219 at 130 m depth (transect 45 on Fig. 1).