1   **High spatiotemporal variability in meiofaunal assemblages in Blanes Canyon (NW**

2   **Mediterranean) subject to anthropogenic and natural disturbances**

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1. ABSTRACT

We investigated the natural and anthropogenic drivers controlling the spatiotemporal distribution of the meiofauna in the submarine Blanes Canyon, and its adjacent western slope (NW Mediterranean margin of the Iberian Peninsula). We analyzed the relationships between the main sedimentary environmental variables (i.e. grain size, Chl-a, Chl-a:phaeopigments, CPE, organic carbon and total nitrogen) and the density and structure of the meiofaunal assemblages along a bathymetric gradient (from 500 to 2000 m depth) in spring and autumn of 2012 and 2013.

Twenty-one and 16 major taxa were identified for respectively the canyon and slope, where the assemblages were always dominated by nematodes. The gradual decreasing meiofaunal densities with increasing depth at the slope showed little variability among stations and corresponded with a uniform pattern of food availability. The canyon was environmentally much more variable and sediments contained greater amounts of food resources (Chl-a and CPE) throughout, leading not only to increased meiofaunal densities compared to the slope, but also different assemblages in terms of composition and structure. This variability in the canyon is only partly explained by seasonal food inputs. The high densities found at 900 m and 1200 m depth coincided with significant increases in food availability compared to shallower and deeper stations in the canyon. Our results suggest that the disruption in expected bathymetric decrease in densities at 900-1200m water depth coincided with noticeable changes in the environmental variables typical for disturbance and deposition events (e.g., higher sand content and CPE), evoking the hypothesis of an anthropogenic effect at these depths in the canyon. The increased downward particle fluxes at 900 to 1200 m depth caused by bottom trawling along canyon flanks, as reported in previous studies, support our hypothesis and allude to a substantial anthropogenic factor influencing benthic assemblages at these depths. The possible relationships of the observed patterns and some major natural environmental (e.g., surface productivity or dense shelf water cascading) and anthropogenic (e.g. the lateral advection and downward transport of food-enriched sediments resuspended by the daily canyon-flank trawling activities) drivers are discussed.

55

56   **2. INTRODUCTION**

57   There is increasing evidence that submarine canyons play important ecological roles
58   in the functioning of deep-sea ecosystems (Amaro et al., 2016; Thurber et al., 2014)
59   Submarine canyons are important routes for the transport of organic matter from surface
60   waters and continental shelf areas to the deep sea basins (Granata et al 1999; Durrieu de
61   Madron et al., 2000; Palanques et al., 2005; Canals et al., 2006; Pasqual et al., 2010),
62   and they contribute significantly to regional biodiversity and secondary production
63   along continental margins (Gili et al., 1999, 2000; Sardá et al., 2009; Ingels et al., 2009;
64   Vetter et al., 2010; De Leo et al., 2010;). Different oceanographic and geological
65   processes are responsible for their role as organic matter supply routes, including slope
66   instabilities, turbidity currents events caused by river floods or episodic storms, and
67   dense shelf water cascading (De Stigter et al., 2007; Allen and Durrieu de Madron,
68   2009; Puig et al., 2014). Additionally, anthropogenic activities along canyon flanks such
69   as bottom trawling can alter seafloor community structure and biodiversity through
70   physical habitat disturbance and the re-suspension of sediments, which ultimately
71   accumulate at greater depths inside the canyon axis (Palanques, et al., 2006; Martín et
72   al., 2008, 2014; Puig et al., 2012, 2015a, b; Pusceddu et al., 2014; Wilson et al., 2015).

73   More than 500 large submarine canyons have been identified in the Mediterranean
74   Sea (Harris and Whiteway, 2011) with several of them located along the Catalan margin
75   (NW Mediterranean). Among those, Blanes Canyon has been intensively studied in the
76   past decade (Zúñiga et al, 2009; Sánchez-Vidal et al., 2012; Canals et al., 2013; Lopez-
77   Fernandez et al., 2013). It has been shown that the canyon axis experiences strong
78   current intensifications coupled with high particle fluxes to the deepest parts of the
79   canyon, which are linked to major events like storms and subsequent river discharges,
80   as well as dense water formation during winter. These characteristics cause the off-shelf
81   sediment transport through the Blanes Canyon axis to vary substantially over time.
82   Moreover, the downward particle fluxes within the canyon can be affected by sediment
83   resuspension caused by daily bottom trawling activities along the canyon flanks
84   (Company et al., 2008, Sardà et al., 2009), with increased fluxes attributed to this

85   process observed mainly between 900 and 1200 m depth (Lopez-Fernandez et al.,

86   2013). In general, the particulate matter fluxes in the canyon area and at the adjacent

87   open slope have two defined seasonal periods (Zúñiga et al., 2009; Lopez-Fernandez et

88   al., 2013). During autumn-winter mass fluxes increase in response to river flooding

89   coupled with major coastal storms. During the spring-summer months the biological

90   component of the particulate fluxes becomes more important as a response to the

91   phytoplankton bloom. However, the open slope mass flux has been reported to be three

92   orders of magnitude lower than inside the Blanes Canyon with sinking particles

93   containing lower amounts of lithogenics and higher levels of organic carbon (OC)

94   (Lopez-Fernandez et al., 2013).

95   Most, if not all, oceanographic and geological processes that drive the ecological

96   function and processes in submarine canyons elicit a response from the canyon fauna

97   (Amaro et al., 2016). Elevated and depressed faunal densities have been reported in

98   canyons, compared to slope areas (Cartes et al., 1994, 2009, 2010; Vetter and Dayton,

99   1998; Garcia and Thomsen, 2008; Ingels et al., 2009, 2013; De Leo et al., 2010;

100 Tecchio et al., 2013; Romano et al., 2013). Complex canyon hydrodynamics can lead to

101 areas characterized by strong deposition next to areas typified by intense erosion

102 processes, which are highly variable in time. These factors have been identified as

103 driving marked temporal and spatial variability in benthic fauna standing stocks (De

104 Bovée, 1990; Ingels et al., 2013; Romano et al., 2013; Tecchio et al., 2013). Despite the

105 difficulties associated with sampling these deep-sea environments, the collection of

106 benthic biological time-series is crucial in providing the necessary information to

107 understand ecological processes and their importance in canyon systems.

108   The main forcing processes affecting canyons influence benthic organisms, and the

109 meiofauna is no exception in this context (Giere et al., 2009). Metazoan meiofauna

110 dominate the deep-sea benthos in terms of abundance and biomass (Vincx et al., 1994;

111 Rex et al., 2006; Giere, 2009; Pape et al., 2013a; Pape et al., 2013b). Quantitative deep-

112 sea meiofaunal studies in the Mediterranean, have mostly focused on slope and basin

113 environments (De Bovée et al., 1990; Soetaert et al., 1991; Tselepides and

114 Lampadariou, 2004; Bianchelli et al., 2008; Romano et al., 2013; Rumolo et al., 2015),

115 while studies targeting wide bathymetric gradients along canyons axes are particularly

116 rare (De Bovée, 1990; García et al., 2007; Bianchelli et al 2010). Meiobenthic taxa,

117 such as Nematoda, seem particularly resilient to both natural and anthropogenic

118 physical disturbance compared to other benthic organisms such as the macrofauna

119 (Pusceddu et al., 2013). However, chronic deep-sea anthropogenic activities such as
120 bottom trawling on canyon flanks can cause a reduction in meiofauna abundance and
121 diversity through a decrease in OM content in the trawled sediments (Pusceddu et al.,
122 2014).

123 The aim of the present work is to study the distribution patterns of the metazoan
124 meiofauna along the Blanes Canyon axis compared with those from the adjacent open
125 slope. Samples were collected covering a bathymetric range from 500 to 2000 m depth
126 in two periods (i.e. spring and autumn) and over two successive years (2012 and 2013)
127 to identify variations in the main meiofaunal descriptors (i.e., density, community
128 composition and richness of taxa). Subsequently, their relationship with the main
129 driving sediment variables (e.g. grain size, organic content), including those related with
130 food input (e.g. Chlorophyll-*a* content), and environmental constraints (both natural and
131 anthropogenic) were analyzed. Based on previous observations from submarine canyon
132 systems we expect that Blanes Canyon will be characterized by high-density meiofauna
133 communities, but also by high temporal community variability which is only partly
134 explained by seasonal differences in food input.

135

136 **3. MATERIAL AND METHODS**

137 *3.1. Sampling*

138 Within the frame of the DosMares research project, sediment samples were
139 collected in and around Blanes Canyon during four cruises (DM-I: early spring 2012,
140 DM-II: autumn 2012, DM-III: spring 2013 and DM-IV: autumn 2013) on board of the
141 R/V García del Cid (Fig. 1). Six stations were sampled along the canyon axis (BC500,
142 BC900, BC1200, BC1500, BC1750 and BC2000) and five on the adjacent open slope
143 (OS500, OS900, OS1500, OS1750 and OS2000). Despite a comprehensive sampling
144 campaign, full temporal and water-depth coverage could not be obtained owing to
145 technical and logistical reasons (see Table 1 for details).

146 Samples for meiofauna and sediment variables were obtained using a 6-tube
147 multicorer KC Denmark A/S (inner diameter 9.4 cm; length 60 cm), yielding samples
148 with an intact sediment-water interface. Between 1 and 3 multicore deployments
149 (replicates) were conducted at each sampling station depending on the cruise (Table 1).
150 From each multicore deployment, one core was used for meiofaunal and three for
151 sediment analyses, which were all carefully sub-sampled on board by means of a small

152 PVC tube (36 mm of diameter, 5 cm sediment depth) taken from the center of the core
153 to maintain a consistent sample surface area for all replicates. Meiofauna samples were
154 fixed in buffered 4% formaldehyde, while those for sediment variables were frozen and
155 stored at -20°C until analysis in the laboratory.
156
157 *3.2. Sediment variables*
158 *3.2.1. Grain size*
159 Grain sizes were analyzed using a Master Sizer 2000 laser analyzer. Each sample
160 was first defrosted and homogenized. Then, aliquots (~1 g) were treated with a 6%
161 hydrogen peroxide solution for 48 h to remove organic matter and subsequently washed
162 with distilled water to eliminate salts. Before each measurement 10 drops of distilled
163 water with sodium hexametaphosphate (0.05 %) was added to disperse the sediment.
164 Then samples were homogenized prior to running the analysis. Sediments were grouped
165 into grain size fractions as follows: clay (<4 μm), silt (4–63 μm) and sand (63 μm–2
166 mm).
167
168 *3.2.2. Geochemical analysis*
169 Aliquots of 0.5 to 5 g of sediment from each sample were freeze-dried to analyze
170 total carbon organic carbon (OC) and total nitrogen (TN) using an elemental analyzer
171 Flash 1112 EA interfaced to a Delta C Finnigan MAT isotope ratio mass spectrometer
172 at the "Centres Científics i Tecnològics de la Universitat de Barcelona". Samples for
173 OC were first de-carbonated using repeated additions of 25% HCl with 60°C drying
174 steps in between until no effervescence was observed (Nieuwenhuize et al., 1994).
175
176 *3.2.3. Pigment content*
177 Sediment aliquots were freeze-dried and homogenized to extract pigments. About 1
178 g dry weight of sediment was mixed in 4 ml 90% acetone and the obtained extract was
179 centrifuged (4 min at 3000 rpm, 4°C) and filtered through a Whatman Anodisc 25 (0.1
180 μm). Pigments were analyzed by Ultra Performance Liquid Chromatography.
181 Chlorophyll-*a* (Chl-*a*) and chlorophyll degradation products were identified by
182 checking the retention times and the absorption spectra against a library based on
183 commercial standard mixtures (DHI, PPS-MiX-1) and extracts from pure cultures of
184 algae and bacteria (protocol modified of Buchaca and Catalan, 2008). Chloroplastic
185 Pigments Equivalents (CPE: sum of Chl-*a* and phaeopigments, its degradation products)

186 was used to estimate OM produced by surface primary productivity. The ratio Chl-*a*:
187 phaeopigments (Chl-*a*:phaeo) was used as a proxy to estimate the freshness of
188 photosynthetically derived OM (Thiel, 1978).

189

190 *3.3. Meiofauna*

191   The fixed samples were rinsed through a 1000 μm mesh then sieved through a
192 32 μm mesh. The retained 32 μm fraction was washed and centrifuged three times using
193 the colloidal silica polymer LUDOX HS40 (specific gravity 1.18) to achieve density
194 gradient separation of the meiofauna (Heip et al. 1985). The supernatant of each
195 washing cycle was again collected on a 32-μm sieve. After extraction, samples were
196 kept in 4 % formaldehyde and stained with Rose Bengal. All metazoan meiobenthic
197 organisms were classified at higher taxon level following Higgins and Thiel (1988) and
198 counted under stereomicroscope (50 x magnification).

199

200 *3.4. Data analyses*

201   Both univariate and multivariate non-parametric permutational (PERMANOVA)
202 analyses were performed to test differences in meiofauna density and assemblage
203 composition, as well as sediment variables between sampled periods, locations and
204 depths. Differences between locations (i.e. canyon *vs* slope) and water depths were
205 tested with two different 2-way crossed designs, using Location (Lo: fixed) and Water
206 Depth (WD: fixed) as factors, both for uni- and multivariate analysis (PERMANOVA
207 Anderson, 2005; Anderson et al., 2008). In the first 2-way PERMANOVA analysis to
208 assess overall differences between locations we pooled the data from the four sampling
209 times and considered all the depths (6 levels: 500, 900, 1200, 1500, 1750, 2000 m).
210 Subsequently, we considered data from each campaign separately and performed a 2-
211 way PERMANOVA analysis for each campaign including only the sampled depths that
212 were in common between canyon and slope (e.g. spring 2012: 1750 and 2000 m;
213 autumn 2012: 1500, 1750, 2000 m; spring 2013: 500, 900, 1500, 1750, autumn 2013:
214 1750 m).

215   Considering that the sampling effort of this study was mainly focused on the
216 canyon and for the slope a less complete data matrix was available, we also analyzed the
217 data from each location separately by means of two-way crossed design using Time

218 (Tm: fixed) and WD (fixed) as factors. For the canyon data the factor WD had 6 levels
219 (500-2000 m, see Table 1) and for the slope it had 3 levels (1500-2000 m).

220   Additional non-metric multidimensional scaling (MDS) visualization was used to
221 show the spatial variations of meiofauna community structure based on Bray Curtis
222 similarity values.

223   Differences in sediment variables over the terms Tm and WD were assessed by
224 univariate PERMANOVA, except for the grain size content, where clay, silt and sand
225 percentages were considered as multivariate variables. Additionally, Principal
226 Component Analyses (PCA) based on sediment variables were performed to assess
227 differences in spatial distribution between the canyon and slope samples and the
228 temporal and spatial patterns in the canyon. Prior to calculating the Euclidean distance
229 resemblance matrix, the full set of 11 available sediment variables was tested for
230 collinearity (Draftsman plot and Spearman correlation) and variables with correlations
231 (R^2) > 0.95 (redundant) were omitted from the analyses (i.e. Chl-*a*:OC and
232 phaeopigments). The data were then checked for uniform distribution (Chl-*a,* CPE and
233 Chl-a:phaeo were log (0.01+X) transformed) followed by normalization (subtracting the
234 mean and dividing by the standard deviation, for each variable) to bring them to a
235 common unit before analysis.

236   The univariate meiofaunal density data were square root transformed and Euclidean
237 distance was used to calculate the resemblance matrix. Multivariate analyses of the
238 meiofauna assemblage composition were done on a Bray-Curtis resemblance matrix
239 based on fourth-root transformed data.

240   Additionally, regression analyses were performed to reveal the form, distribution
241 and significance (null hypothesis rejected when the significance level was > 5%) of the
242 functional relationships between each dependent variable (sediment variables and
243 meiofauna density, using water depth as independent variable) and assess the
244 differences between canyon and slope samples.

245   Spearman correlations were used to assess the strength of the relationship between
246 the selected sediment variables and meiofauna density (based on the complete data set,
247 including both canyon and slope samples). Finally, the relationships between meiofauna
248 composition and sediment variables were investigated using the Distance based Linear
249 Model routine (DISTLM) in PERMANOVA + (Anderson et al., 2008). The DISTLM
250 assemblage was built using a step-wise selection procedure and adjusted R^2 was used as
251 selection criterion.

252   All described analyses were performed using PRIMER v6 with PERMANOVA +

253   add-on software (Clarke and Gorley, 2006; Anderson et al., 2008) and XLSTAT

254   (Addinsoft) software.

255

256   *3.5. Ancillary data*

257   To assess the impact of bottom trawling fisheries in the Blanes canyon, positioning

258   of fishing vessels was obtained from the Fishing Monitoring Centre of the Spanish

259   General Secretariat of Maritime Fishing (SEGEMAR) as Vessel Monitoring System

260   (VMS) data, a protocol established by the Common Fisheries Policy of the European

261   Union (2011). Each vessel equipped with VMS provide its registered harbour, heading,

262   speed and Global Positioning System coordinates with an error margin of 100 m, and

263   transmits this information by Inmarsat-C to the Fishing Monitoring Centre in less than

264   10 min at 2-hour time intervals (Gerritsen et al., 2013). VMS positioning from bottom

265   trawlers operating in the study area during 2006-2013 was subsequently converted to

266   fishing effort (hours/km^2), computed in grid cells of 0.5´ latitude x 0.5´ longitude as

267   shown in Figure 1, following the method and the software tools described in Hitzen et

268   al. (2012).

269   To assess the relative role of the various oceanographic processes contributing to the

270   temporal variability of downward particle fluxes in the study area during the study

271   period, surface primary production was obtained from satellite data of chlorophyll-a

272   concentration at www.nasa.gov. Daily river discharge series measured at the nearest

273   gauging station to Tordera River mouth was obtained from *Agència Catalana de*

274   *l´Aigua* (ACA) and significant wave height was provided by *Puertos del Estado*

275   (www.puertos.es).

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277

278   **4. RESULTS**

279   *4.1. Sediment characteristics*

280   Canyon and slope sediments were predominantly muddy (2-63 µm) with high silt

281   content (62% to 77%, respectively) over the whole bathymetric gradient (Table 2).

282   Sediments were in general characterized by a high sand content in the canyon, except at

283   BC2000 (pair-wise comparison Lo x WD, $p < 0.01$, Fig. 2, Table 2). Along the slope,

284   sediments became progressively finer with increasing water depth ($R^2 = 0.79$ and 0.39

285 respectively for clay and sand, $p < 0.05$, Fig. 2; Table 2; PERMANOVA, $p < 0.05$,
286 Table 4) whilst in the canyon there was no consistent bathymetric trend (Fig. 2). In
287 general (slope and canyon samples pooled), grain size decreased until BC900, peaked at
288 BC1200 and, then decreased again with depth (Table 2).

289   Sedimentary Chl-*a* and CPE content were higher in the canyon than at the slope,
290 except for Chl-*a* at BC500 in spring 2013 (Fig. 2, Table, Table 3). Slope samples
291 exhibited decreasing Chl-*a* and CPE with increasing water depth (R^2=0.58 and 0.65
292 respectively, $p < 0.05$, Table 4; Fig. 2). Sedimentary Chl-a content was different
293 between sampling periods (Tm x WD interaction, pairwise comparisons, $p < 0.01$, Table
294 4), particularly at OS1750 between spring and autumn 2012 ($p< 0.05$, Table 2). CPE did
295 not differ between sampling periods (Table 4). Along the canyon axis, Chl-*a* decreased
296 with increasing water depth (Fig. 2, R^2=0.26) but the high variability at BC1200
297 (autumn 2012 and spring 2013) and BC1500 (spring 2012) obscured this general pattern
298 (Table 2). Chl-*a* differed significantly between sampling periods and water depths
299 (PERMANOVA, $p < 0.01$, Table 4). As for Chl-*a*, CPE decreased with increasing water
300 depth along the canyon axis, except for the peaks observed at BC1200 (autumn 2012
301 and spring 2013) and BC1500 (spring 2012) (Table 2, PERMANOVA, $p < 0.01$, Table
302 4).

303   The "freshness" (Chl-*a*: phaeo ratio) of OM did not differ significantly between the
304 canyon and slope (PERMANOVA, $p > 0.05$, Table 3). At the slope, the freshness of
305 OM did not show a clear decrease with increasing water depth (Fig. 2F) and differences
306 between sampling periods were not significant (PERMANOVA, $p > 0.05$, Table 4). In
307 the canyon, the freshness differed significantly between sampling periods and water
308 depths, but a clear decrease with increasing depth occurred only in spring 2012 (Table
309 2; PERMANOVA, $p < 0.01$, Table 4). There were also significant differences between
310 spring and autumn 2012 for BC500, BC900 and BC1500 and between autumn 2012 and
311 2013 at BC1750 and BC2000 (Tm x WD interaction, pairwise comparisons, $p < 0.01$,
312 Table 4).

313   Sedimentary OC and TN differed significantly between the canyon and slope
314 (PERMANOVA, $p < 0.05$, Table 3), with the main differences occurring at 500 m depth
315 and the 1500-2000 m stations for OC and at 500 m and 1750 m depth for TN (pair-wise
316 comparison, $p < 0.05$, see Fig. 2). At the slope, OC and TN differed significantly
317 between sampling periods (Table 4), particularly between autumn 2012 and spring 2013
318 ($p < 0.05$, see Table 2). Also TN and OC differed significantly between water depths

319 (Table 4) but only TN decreased with increasing depth ($R^2 = 0.27$; Fig. 2). Along the
320 canyon axis, OC and TN differed significantly between sampling periods and water
321 depths (PERMANOVA, $p < 0.01$, Table 4), with a pronounced decrease with increasing
322 water depth in spring 2013 (Table 2). OC and TN were significantly higher in spring
323 2013 and autumn 2012 (Table 2). TN also differed significantly between 2012 and
324 2013, particularly at BC1500 and BC1750 (Tm x WD interaction pairwise comparisons,
325 $p < 0.01$, Table 2, 4).

326 Sedimentary C:N ratios did not differ significantly between canyon and slope
327 (PERMANOVA, $p > 0.05$, Table 2, 3, Fig. 2). Along the canyon axis, C:N differed
328 significantly between sampling periods (PERMANOVA, $p < 0.01$, Table 4), particularly
329 between the years 2012 and 2013 (Table 2).

330 Canyon and slope samples separated in the PCA (Fig. 3A). Furthermore, slope
331 samples were less variable in terms of environmental variables, except for OS500. The
332 first two PC axes explained a 69.6% of the variation. The main contributors were Chl-a
333 (-0.443), CPE (-0.388), Chl-*a*:phaeo (-0.374) and clay (0.367) for the axis PC1 and silt
334 (-0.562), TN(-0.468), sand (0.450) and OC (-0.396) for the axis PC2 (numbers in
335 parenthesis represent eigenvector values).

336 When the Canyon axis samples were analyzed separately, the first two axes of the
337 PCA explained 65.4% of the variation (41.5% and 23.9% for PC1 and PC2,
338 respectively; Fig 3B). The main contributors were sand (0.427), Silt (-0.392), Chl-*a*
339 (0.379) and TN (-0.357) for PC1 and OC (0.596), Chl-*a* (0.376), sand (-0.388) and CPE
340 (0.310) for PC2 (numbers in parenthesis represent eigenvectors). Sampling periods were
341 clearly distinguishable in the PCA plot (Fig. 3B), particularly autumn 2012 and spring
342 2013, in accordance with the PERMANOVA analyses (Table 4). In particular spring
343 2013 samples were characterized by having greater pigments concentrations (Table 2)
344 as suggested by the PCA. No consistent bathymetric differences could be observed in
345 the PCA plot.

346

347 *4.2. Meiofauna density*

348 In general, total meiofauna densities were significantly higher inside the canyon
349 than on the slope (Table 5; $p < 0.01$, Table 7, Fig. 4), particularly during spring 2012
350 and autumn 2012 (Table 5) at 1750 and 2000 m depth (pair-wise comparison, $p < 0.05$,
351 data not shown, see Fig. 4).

352   At the slope, there were significant differences between depths (PERMANOVA,
353    $p < 0.01$, Table 6), and a density decrease with increasing water depth (R^2=0.84, p<
354   0.005, Fig. 4) was observed. There was little between-replicate variability in density at
355   each station along the slope, in contrast to the high variability observed in the canyon
356   (Table 6). The minimum slope density recorded was 209 ± 44 ind. 10 cm^{-2} at OS2000 in
357   autumn 2012 and the maximum was 1027 ± 72 ind. 10 cm^{-2} at 500 m depth in spring
358   2013 (Table 7, Fig. 5B).

359   Along the canyon axis, the densities did not show a clear bathymetric pattern,
360   and they were characterized by high variability over the different sampling periods
361   within and between depths (Fig. 4, 5 A). The minimum density recorded was 378 ± 69
362   ind. 10 cm^{-2} at BC900 in spring 2012 and the maximum was 1763 ± 245 ind. 10 cm^{-2} at
363   BC500 in autumn 2012 (Table 7, Fig. 5 A). The highest variability was observed at
364   BC900 and BC1200 (Fig.5 A). There was a significant influence of water depth at each
365   sampling period, except in spring 2013 (PERMANOVA, $p < 0.05$, Table 6). In fact, the
366   observed differences were caused by the densities at BC500, which were significantly
367   higher than those at the deepest stations (BC1500, except in spring 2012, BC1750 and
368   BC2000) (Table S1, pair-wise comparison within Tm x WD; Fig 5 A).

369

370   Regarding the temporal variability, at the slope stations, meiofauna densities did
371   not exhibit significant differences at any sampling depth (PERMANOVA, $p > 0.05$,
372   Table 6; Fig. 5B). In contrast, densities inside the canyon differed significantly between
373   sampling periods (Fig. 5A, Table 6), but no clear seasonal patterns were observed. In
374   2012, densities were higher in autumn than in spring, (except at BC1500) while the
375   trend was the opposite in 2013 (except at BC900) (Fig. 5A). Significant intra-annual
376   differences occurred in 2012 at BC1750, with higher densities in autumn compared to
377   spring. Significant inter-annual variability mainly occurred between autumn periods at
378   BC500 and BC1750, where densities were higher in 2012 than 2013, and at BC900,
379   where the opposite was observed (Table S1, pair-wise comparisons). There were no
380   temporal differences detected at stations BC1200, BC1500 and BC2000 (Table S1, pair-
381   wise comparison; Fig 5A).

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386 *4.3. Meiofauna community composition*

387   The meiofauna composition in the canyon and the slope was comparable to what is

388   usually observed in the deep sea, with nematodes being dominant (79.2-97.6 %),

389   followed by copepods (0.68-5.14%, mainly harpacticoids), nauplii larvae (0.65-4.9%)

390   and polychaetes (0.51-3.12%) (Table 7). Other taxa (such as tardigrades and

391   kinorhynchs) were regularly found but in low densities (less than 2%). A total of 21

392   major taxa were identified in the canyon, while only 16 taxa were collected at the open

393   slope. Aplacophora, Amphipoda, Nemertea, Cumacea and Sipunculida were only

394   present in the canyon samples (Table 7). Relative nematode abundance was slightly

395   higher in all canyon samples compared to slope samples, except at the 900 m and 1750

396   m stations in spring 2013 and autumn 2013, respectively.

397   Considering all samples, meiofauna composition differed significantly between the

398   canyon and the slope (Table 6, p< 0.05), except at the 900 m stations (Lo x WD, pair-

399   wise comparison, p <0.05). For each sampling period, differences between locations

400   were also evident, especially in spring and autumn 2012 (Table 6). At the slope,

401   meiofauna composition varied between water depths (Table 6). The maximum of 13

402   taxa was found at OS1500 in autumn 2012 and the minimum number of 5 taxa was

403   found at OS1750 in autumn 2013, Despite of the reduced number of slope samples, the

404   number of taxa decreased with increasing water depth in autumn 2012 and spring 2013

405   (Table 7). In the canyon, the meiofauna community structure also differed among water

406   depths (Table 6), except for the BC500-BC1200, BC900-BC1200, BC1500-BC1750

407   and BC1750-BC2000 pairwise comparisons (Table S2). However, the MDS ordination

408   showed that there were no clear relationships between meiofauna community structure

409   and bathymetry, except in autumn 2013 (Fig. 6). The maximum number of taxa (14)

410   was found at BC900 in autumn 2012 and spring 2013 and the minimum (6) at BC2000

411   in autumn 2013 (Table S1). The reduced dominance of nematodes at BC900 is

412   countered by a relative increase of copepod and nauplii densities (Table 7).

413

414   The structure of the slope assemblages did not differ between sampling periods

415   (Table 6), despite there was an increase in number of taxa from spring to autumn 2012

416   (Table 7). In the canyon, there were clearly significant time differences (Table 6), with

417   the most significant variations occurring both in 2012 (intra-annual) and between the

418   two autumn periods (inter-annual, 2012-2013) (Table 6, Table S2, pair-wise

419 comparison). These differences were mainly owing to the increase in number of taxa
420 from spring to autumn 2012 at all sampling stations (except at BC2000) (Table 7).
421
422 *4.4. Relationship between meiofauna and environmental variables*
423   Meiofaunal densities showed significant, positive correlations with the variables
424 representing food inputs (i.e. CPE, Chl-*a*, and OC) both in the canyon and at the slope,
425 but correlations were higher for the slope than in the canyon (Spearman correlation,
426 Table 8). At the slope, negative correlations between meiofauna densities and TN and
427 Clay were found, while a positive correlation with Sand occurred along the canyon axis.
428   Environmental variables all together explained 43% and 18% of the observed
429 variation in meiofauna community structure in the slope and in the canyon, respectively
430 (Table S3, S4, DISTLM), with the main contributor being Chl-*a*, (24% and 9%,
431 respectively). Other variables significantly contributing were Clay, Silt, OC, C:N and
432 CPE at the slope, and Clay, Sand, TN, CPE and Chl-*a*: phaeo in the canyon.
433
434 **5. DISCUSSION**
435   The Mediterranean is considered to be an oligotrophic sea, a characteristic which
436 is often used to explain its typically low deep-sea meiofauna densities compared to
437 similar depths in other oceans (Soltwedel, 2010; Bianchelli et al., 2010; Pape et al.,
438 2013b). Mediterranean meiofauna densities range between 4 and 1497 ind. 10 cm^{-2}, with
439 a clear decrease from west to east (Soltwedel, 2000; Bianchelli et al., 2010) which has
440 been linked to the W-E gradient of increasing oligotrophy (Danovaro et al., 1999;
441 Gambi and Danovaro, 2006; Danovaro et al., 2008). Similar low density ranges have
442 only been reported in the Southern Pacific Ocean, Southern Atlantic Ocean and Artic
443 Ocean (see Bianchelli et al., 2010 for a review).
444   The maximum densities in the Blanes Canyon axis were higher than those
445 observed in other Mediterranean canyons (Table 9). Minimum densities were equivalent
446 to those of Cape of Creus Canyon, but about 5 to 8 times higher than in the remaining
447 canyons, even when compared to previous data from Blanes Canyon (Romano et al.,
448 2013) (Table 9). The study by Romano et al. (2013) included only a few canyon stations
449 and a limited depth range, with samples from the eastern and western canyons flanks
450 (900 m depth), from the canyon axis (1600 m depth), and from the eastern open slope
451 (1600 m depth). In the present study, a much more comprehensive range of samples
452 were obtained, including different seasons and years, and covering the canyon axis over

453   a wide bathymetric gradient, whilst also including stations from the adjacent western

454   open slope, allowing a broader temporal and spatial assessment of the meiofauna in the

455   Blanes Canyon system.

456

457   *5.1. Spatial and temporal distribution of the meiofauna in the Blanes Canyon system*

458   Contrary to the traditional perception that the whole of the deep-sea is a stable

459   environment (e.g. Sanders, 1968), marked temporal variations of meiofaunal organisms

460   have been observed in submarine canyons (De Boveé et al., 1990; Romano et al., 2013;

461   Ramahlo et al., 2014; Rumolo et al., 2015) and slope systems (e.g., Hoste et al., 2007;

462   Romano et al., 2013; Guidi-Guilvard et al., 2014). Such variations generally suggest

463   contrasting scenarios between spring-summer and autumn-winter, with the former

464   causing higher densities. Traditionally, this variability has often been associated to the

465   seasonal trends in phytodetrital food availability, but it could also be associated with

466   specific particulate matter transport mechanisms, particularly in submarine canyon

467   environments (Pusceddu et al., 2013; Ramalho et al., 2014).

468   Previous studies in the Blanes Canyon have revealed high variability in particle

469   fluxes, driven by a variety of causes: storms, dense water formation (by dense shelf

470   water cascading and open sea convection), dust inputs, phytoplankton blooms, and

471   bottom trawling (Lopez-Fernandez et al., 2013). The concatenation of such events

472   influences sedimentary dynamics and ultimately meiofauna communities by altering

473   sediment characteristics and food availability. Physical disturbances occurring in

474   submarine canyons sediments are known to drive the composition of meiobenthic

475   communities (Aller, 1997; Garcia et al., 2007; Ingels et al; 2009; Levin et al., 2012;

476   Romano et al., 2013).

477

478   During the study period, temporal differences in meiofauna density and

479   community composition have been observed mainly in the Blanes Canyon axis, with

480   slope sediments showing much lower meiofaunal variability. Despite the potential bias

481   caused by the reduced number of slope samples in our study, our results are consistent

482   with observations by Romano et al. (2013). In their study, meiofaunal densities at 800

483   and 1600 m depth on the eastern slope reflected a less dynamic environment compared

484   to canyon stations between spring and autumn at those depths. Additionally, in our

485   study, meiofauna densities and composition also differed between sampling years inside

486   the canyon (Table 6). These differences seemed to be related to the observed increase of

487   primary productivity in spring 2013 (Fig. 7A), which occurred on the slope, but was

488   particularly reflected in the canyon sediments, where the sedimentary Chl-a content in

489   2013 was much higher than in 2012. Significant positive correlations between

490   meiofaunal densities and Chl-a support this observation (Table 8). The C:N ratios

491   showed a similar pattern, with increased values in 2013 compared to 2012 (Table 2),

492   which is likely related to greater terrestrial runoff from the rivers in 2013 (Fig. 7B)

493   combined with the resuspension caused by the high waves registered during spring 2013

494   (Fig. 7C). However, the responses of the meiofaunal assemblages were not

495   homogeneous along the studied bathymetric range; likely an indication of other factors

496   that can alter food availability in the canyon-slope sediments and ultimately meiofauna

497   densities and community composition.

498   For instance, the food signals detected in the sediments (in terms of CPE and

499   Chl-a, see Table 2), together with the sand content (Table 2), were highly heterogeneous

500   in the upper canyon region and tended to be higher at BC1200. In this area, canyon

501   flank tributaries (see Lastras et al., 2011) connect the canyon axis with some of the most

502   frequently trawled grounds along the canyon rims (Fig. 1). As previously mentioned,

503   Blanes Canyon and its adjacent open slopes comprise fishing grounds that have been

504   subjected to persistent bottom trawling down to 800 m depth (Company et al., 2008;

505   Sardà et al., 2009; Ramirez-Llodra et al., 2010). The main effort concentrates along the

506   northern open slope from late winter to early summer and over the eastern canyon rim

507   from late summer to mid-winter (Company et al., 2008; Sardà et al., 2009; Ramirez-

508   Llodrà et al., 2010). Data from moored sediment trap data in Blanes Canyon, recorded

509   increase in particle fluxes (mostly lithogenic) recorded at 900 and 1200 m depth in the

510   canyon axis (mainly in summer) that was attributed to the formation of sediment

511   resuspension clouds by bottom trawling activities (Lopez-Fernandez et al., 2013). Our

512   results show major differences in sediment composition (coarser) and meiofaunal

513   densities (higher) at BC900 and, particularly, at BC1200 (Table 2; Fig 5A), which

514   interrupts the expected distribution patterns under normal slope conditions. Altogether,

515   these observations indicate the possible presence of an anthropogenic depocenter (i.e. a

516   preferential area of sediment accumulation by trawling) at these depths in the Blanes

517   Canyon axis in a similar way to the ones previously reported in the nearby La Fonera

518   Canyon, Arenys and Besòs submarine canyons (Martín et al., 2008; Puig et al., 2015a,b;

519   Fig. 1). Therefore, we suggest that the processes involved in the formation of

520   sedimentary deposits caused by bottom trawling activities may be an important driver

521   for meiofaunal assemblages in canyon axes environments. Contrary to the negative

522   direct effects of trawling over fishing grounds in canyon flanks (Pusceddu et al., 2014),

523   the increased levels of OM around sedimentary depocenters are likely beneficial to the

524   organisms living in the canyon axis, including the meiofauna. For instance, in La

525   Fonera Canyon the burrowing echinoid *Brissopsis lyrifera* (Forbes, 1841) colonized and

526   proliferated in the lower canyon axis (Mecho et al., 2014) following the formation of an

527   anthropogenic deposit of fine-grained material (Puig et al. 2015a).

528   The relatively low densities detected at BC500, BC900 and BC1200 in the

529   canyon axis in spring 2012 (Fig. 5A), however, seem to correspond to effects of a major

530   (i.e. deep) dense shelf water cascading event at the NW Mediterranean margin in winter

531   2012 (see Durrieu de Madron et al., 2013). Such oceanographic process might have

532   generated strong down-slope currents causing mechanical removing or burying of

533   resident organisms. Consequently, this may lead to massive dispersal, growth inhibition,

534   or even mortality of the meiofaunal component as has been previously reported in the

535   Cap de Creus Canyon during the major deep cascading event in 2005 (Pusceddu et al.,

536   2013). After the cascading event, the densities and number of taxa in autumn 2012 were

537   much higher than in the previous spring, and also than those in autumn 2013, as dense

538   shelf water cascading was less intense in 2013 and had almost no impact in Blanes

539   Canyon (Anna Sanchez-Vidal, personal communication).

540   The meiofaunal communities in the deeper areas of the canyon, particularly at

541   BC1500 and BC2000 seemed to be more stable over time (Fig. 5 A) where the effects of

542   the anthropogenic (i.e. trawling) and natural (i.e. cascading) disturbances are likely to be

543   much reduced. Conversely, we could not find a straightforward explanation for the

544   relatively high variability observed at BC1750, highlighting the complexity of the

545   biological, chemical and physical interactions driving the spatial and temporal

546   variability within the meiofaunal assemblages in submarine canyon environments

547   (Ingels et al., 2013; Ramalho et al., 2014).

548

549

550   *5.2. Slope v.s Canyon*

551   Decreasing meiobenthic densities with increasing water depth has been

552   postulated as a basic principle in deep-sea ecology (e.g., Thiel, 1983; Tietjen, 1992),

553   and has been linked to the bathymetric decrease in organic matter supply (POC flux)

554   and the increasing distance from land (e.g. Soetaert et al., 1991; Danovaro et al., 1995;

555 Gooday et al., 1996; Fabiano and Danovaro, 1999; Soltwedel, 2000; García et al., 2007,

556 García and Thomsen, 2008). However, as previously mentioned, such a depth-density

557 relation may be modified by the presence of submarine canyons owing to their

558 topographical and hydrographic heterogeneity. Canyons induce modifications in the

559 hydrodynamic and biogeochemical processes of channeling organic matter towards the

560 deep basin. Food availability and meiofauna density in canyons are generally higher

561 compared to canyon interfluve areas at similar depths (De Bovée, 1990; Soetaert et al.,

562 1991; García and Thomsen, 2008; Koho et al., 2008; Ingels et al., 2009; Gambi and

563 Danovaro, 2016; Amaro et al., 2016; Ingels et al., 2011) and Blanes Canyon is no

564 exception in this context.

565 Mediterranean canyon and slope habitats seem to lack consistent bathymetric

566 patterns, especially in the western basin (Bianchelli et al., 2010; Pusceddu et al., 2010).

567 In Blanes Canyon, significant decreases in meiofaunal densities with depth were

568 reported during autumn, while the spring trends were markedly more fluctuant (Romano

569 et al., 2013). This bathymetric pattern, however, was not uniform as it was not clearly

570 observed at the eastern open slope adjacent to the canyon.

571 Our results revealed a bathymetric decrease of meiofaunal density at the slope,

572 but not in the canyon (Fig. 4). For instance, in the canyon axis, meiofauna was less

573 abundant at BC900 than at the deeper stations (BC1500, BC1750 and BC2000) in

574 spring 2012, but it was higher in autumn 2013 (Fig. 5A), likely as a result of the

575 combined canyon heterogeneity and the oceanographic and anthropogenic drivers

576 favoring a higher variability along the axis (see section 5.1). It was clear that densities

577 inside the canyon were higher than those at the western slope, and this was particularly

578 evident for the deepest stations (BC1500, BC1750 and BC2000). However, the deep

579 canyon stations exhibited high temporal meiofauna density variability, almost double

580 the variability observed for the slope (i.e. 31% vs. 16.6% on average, respectively).

581 These results provide further evidence that a heterogeneous canyon environment can

582 lead to meiofaunal assemblages with highly variable distributional patterns in space and

583 time, whilst slope environments tend to be more stable as evidenced by the uniformity

584 of meiofauna density and community structure at the western (present study) and

585 eastern slope (Romano et al., 2013).

586 We observed a decrease in sedimentary food sources (e.g. phytopigments) with

587 increasing depth along the slope; a pattern which agrees with previous findings

588 (Soetaert et al., 1991; Koho et al., 2008; Ingels et al; 2009; among others) and is likely

589   related to the dynamics of the particle fluxes in Blanes Canyon (Zúñiga et al., 2009;
590   Lopez-Fernandez et al., 2013). Moreover, sedimentary phytopigment values were much
591   lower at the slope than in the canyon, which supports the view of canyons playing
592   important roles in catching and channeling organic inputs (Fig. 2). A similar depth-
593   related pattern was observed for meiofauna density and composition (Table 7), which
594   show low temporal variation and positive correlations with food sources (Chl-*a*, CPE,
595   Chl-*a*:phaeo), suggesting a causal relationship.

596   In the canyon, the high variability within and between depths along the axis,
597   both in terms of meiofauna density and sediment variables (Table 2; Fig. 5 A) prevent
598   us from finding a clear relationship. This is likely an indication that meiofaunal
599   distribution can only be partly explained by the variability in food availability under
600   canyon settings. The observed variability can, in turn, be traced back to hydrodynamic
601   forcing, the topographic heterogeneity and/or physical anthropogenic impacts driving
602   the canyon system (Levin et al., 2012; Gambi et al., 2010. Pusceddu et al., 2014).

603   Sediment grain size is known to be a key actor in driving meiofauna
604   distributions (Giere et al., 2009). In the slope, sample sediments tend to be coarser in the
605   shallow parts compared to the deeper parts, and meiofauna showed a strong negative
606   correlation with clay content (Fig. 2). An increase in the fine sediment fractions leads to
607   more compacted sediments, causing a reduction in the interstitial space available for
608   meiofaunal organisms. In the canyon, sand content was positively related with
609   meiofauna density (Table 8). All canyon axis samples (except the shallowest one at
610   BC500) contained coarser sediments than those at the slope presumably caused by the
611   local sedimentological and hydrological conditions and was reflected in the higher
612   meiofauna densities. Grain size trends illustrate the physical dynamism and variable
613   conditions along the axis in the Blanes Canyon, except at BC2000, where the conditions
614   appear to be similar to those in the slope.

615   Slope and canyon systems clearly differ in meiofaunal composition (Table 5)
616   with more rare taxa (i.e., other than nematodes, copepods, nauplii and polychaetes), and
617   generally in greater numbers in the canyon than at the slope. This stands in contrast to
618   the study by Gambi et al. (2010) but supports several other studies that claim submarine
619   canyons to be *hotspots* of benthic biodiversity and biomass in the deep-sea at least in
620   terms of rare meiofaunal taxa (e.g. Danovaro et al., 1999; Gili et al. 2000; De Leo et al.,
621   2010; Ramírez- Llodra., et al., 2010; Vetter et al., 2010).

622

623

Conclusions

624

625   The sedimentary environments within and nearby the Blanes submarine canyon

626   are subjected to numerous and heterogeneous processes occurring with distinct

627   frequencies and intensities over time, and, leading to cyclic episodes of deposition,

628   resuspension and transport. In addition to this natural variability, the influence of

629   anthropogenic activities, particularly intensive bottom trawling fisheries, reveals to be a

630   key factor affecting both geological and biological processes.

631   Our results confirm that Blanes Canyon compared to its adjacent open slope,

632   exhibits (1) larger sediment properties variability, (2) higher meiofaunal densities, and

633   (3) more diverse meiofauna communities.

634   Densities show a clear bathymetric gradient at the western open slope, a gradient

635   that appears disrupted along the canyon axis. The lateral advection and accumulation of

636   food-enriched shallow-water sediments resulting from bottom trawling activities along

637   the canyon rims seems to be the cause of an increase in meiofauna density and diversity

638   at BC900 and, particularly, at BC1200.

639   The temporal variability observed in the canyon meiofauna is only partly explained

640   by the seasonal patterns of food input. Major oceanographic processes such as recurrent

641   dense shelf water cascading events seem to play a key role.

642   Nematodes dominate in all studied environments, and are therefore major

643   contributors to the observed meiofaunal patterns. It is expected that further studies

644   based on high-resolution taxonomic identification of this group, as well as the usage of

645   other descriptors such as biomass or stage/sex-ratio distributions, will contribute to

646   clarify the observed meiofaunal patterns and the extent of their bathymetric and

647   seasonal responses to the environmental changes driving the functioning of Blanes

648   Canyon.

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993 **Table 1.** Sampling stations, geographical position, depth range (minimum – maximum)

994 and sampling intensity. BC: Blanes canyon, OS: open slope.

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Station	Latitude	Longitude	Water Depth (m)	Sampling intensity			
				Spring 2012	Autumn 2012	Spring 2013	Autumn 2013
BC500	41°38´66´´N	02°52´75´´E	462-484	2	2	1	3
BC900	41°34´28´´N	02°50´95´´E	835-903	2	3	3	3
BC1200	41°30´93´´N	02°51´07´´E	1194-1258	2	2	3	–
BC1500	41°27´37´´N	02°52´93´´E	1457-1520	2	3	3	3
BC1750	41°21´51´´N	02°52´07´´E	1726-1785	2	3	3	3
BC2000	41°14´90´´N	02°52´97´´E	1943-1980	2	3	–	–
OS500	41°19´10´´N	02°46´75´´E	493-509	–	–	3	–
OS900	41°16´29´´N	02°48´96´´E	887	–	–	1	–
OS1500	41°08´28´´N	02°53´75´´E	1451-1480	–	3	3	1
OS1750	41°06´79´´N	02°57´02´´E	1731-1751	2	3	3	1
OS2000	41°02´65´´N	03°01´22´´E	1975-1998	2	3	–	–

Table 2. Mean ± standard deviation values of environmental variables for each year at each station, BC: Blanes canyon; OS: Open slope, Spr: Spring; Aut: Autumn; Clay, Silt, Sand: volume percent clay, silt and sand content; TN: total nitrogen concentration; C:N: molar carbon/nitrogen ratio; OC: organic carbon concentration; Chl-a: chlorophyll a; CPE: chloroplastic pigment equivalents; Chl-a:phaeo: chlorophyll a divided by its degradation products (phaeopygments) indicating "freshness" of the phytodetrital OM.

Station	Sampling period	Clay (%)	SD	Silt (%)	SD	Sand (%)	SD	CPE (µg/g)	SD	Chl-a (µg/g)	SD
BC500	Spr-12	19.75	1.5	66.14	8.1	14.11	9.53	2.71	0.85	0.17	0.045
	Aut-12	19.28	0.5	73.16	0.8	7.555	0.29	4.07	1.28	0.13	0.018
	Spr-13	20.29	0	65.51	0	14.2	0	3.98	0	0.46	0
	Aut-13	21.22	0.4	71.01	0.6	7.768	0.92	2.9	0.06	0.26	0.029
BC900	Spr-12	21.72	0.7	70.86	3.2	7.422	3.97	2.23	1.29	0.07	0.014
	Aut-12	18.23	1.9	73.11	0.9	8.658	1.75	3.45	1.11	0.07	0.034
	Spr-13	17.8	0.8	71.12	1.5	11.08	2.25	3.19	1.49	0.15	0.113
	Aut-13	18.58	1.9	72.99	2.5	8.427	3.44	3.98	2.73	0.18	0.072
BC1200	Spr-12	16.02	3.9	62.37	5.6	21.6	9.55	1.3	1.43	0.07	0.055
	Aut-12	18.7	1.6	68.89	3.3	12.51	4.87	4.7	0.11	0.1	0.007
	Spr-13	16.9	1	67.2	2.4	15.9	3.45	5.71	1.5	0.29	0.162
	Aut-13	–	–	–	–	–	–	–	–	–	–
BC1500	Spr-12	17.68	1.5	71.8	8.2	10.52	9.71	3.96	1.39	0.18	0.099
	Aut-12	18.48	0.9	77.07	0.5	4.448	1.39	2.02	0.83	0.03	0.009
	Spr-13	16.18	2	65.09	3.6	18.73	5.53	1.94	0.47	0.12	0.082
	Aut-13	16.54	1.4	70.62	3.9	12.85	5.22	2.23	0.87	0.09	0.02
BC1750	Spr-12	20.43	1	74.99	0.3	4.585	0.73	2.16	0.46	0.07	0.008
	Aut-12	19.32	0.3	75.85	1.2	4.831	1.08	1.27	0.4	0.04	0.015
	Spr-13	17.22	1.2	71.55	2.8	11.23	2.53	2.62	0.77	0.12	0.021
	Aut-13	19.49	0.5	75.47	0.8	5.042	0.94	3.35	1.57	0.1	0.045
BC2000	Spr-12	18.86	0.2	74.85	0.7	6.282	0.53	0.78	0.12	0.02	0.011
	Aut-12	21.33	0.7	73.47	0.7	5.202	0.82	0.87	0.31	0.02	0.008
	Spr-13	–	–	–	–	–	–	–	–	–	–
	Aut-13	19.18	1.5	72.93	1.3	7.882	2.82	1.2	0.3	0.07	0.023
OS500	Spr-13	14.35	0	62.88	4.9	22.76	2.13	2.49	0	0.23	0.17
OS900	Spr-13	17.57	0	80.3	0	2.13	0	2.65	0	0.07	0
OS1500	Aut-12	23.57	0.3	71.96	0.3	4.46	0.16	0.38	0.18	0.01	0.005
	Spr-12	21.74	0.8	73.47	0.5	4.79	0.54	1.36	0.55	0.03	0.016
OS1750	Spr-12	23.82	1.4	69.78	6	6.5	0.98	0.53	0.3	0.02	0.003
	Aut-12	24.38	0.9	70.1	0.8	5.52	0.2	0.29	0.27	0	0
	Spr-13	24.66	0	71.81	0	3.53	0	0.35	0	0.01	0
	Aut-13	24.24	0	71.91	0	3.85	0	0.31	0	0.02	0
OS2000	Spr-12	21.65	6.9	65.95	2.3	12.4	8.62	0.28	0.3	0	0
	Aut-12	24.38	1.2	70.1	0.8	5.52	0.12	0.67	0.26	0.01	0.006

Table 2: *continued*

Station	Sampling period	Chl-*a*:phaeo (µg/g)	SD	OC (%)	SD	TN (%)	SD	C:N	SD
BC500	**Spr-12**	1.074	0.3	0.773	0.1	0.1	0.01	7.71	0.47
	Aut-12	0.054	0.1	0.897	0	0.113	0	7.92	0.1
	Spr-13	0.024	0	1.12	0	0.097	0	11.6	0
	Aut-13	0.248	0.1	1.092	0.1	0.094	0.01	11.7	2.07
BC900	**Spr-12**	0.222	0.1	0.785	0.1	0.098	0.01	7.99	0.41
	Aut-12	0.066	0	0.734	0.1	0.093	0.01	7.87	0.12
	Spr-13	0.193	0	0.871	0	0.081	0	10.7	0.57
	Aut-13	0.259	0.1	0.883	0.1	0.083	0	10.6	0.32
BC1200	**Spr-12**	0.271	0.2	0.56	0.3	0.075	0.03	7.34	0.83
	Aut-12	0.063	0	0.753	0	0.093	0.01	7.74	0.16
	Spr-13	0.102	0	0.886	0	0.078	0	11.4	0.2
	Aut-13	–	–	–	–	–	–	–	–
BC1500	**Spr-12**	0.136	0	0.755	0	0.103	0	7.36	0.08
	Aut-12	0.053	0	0.758	0	0.106	0.01	7.2	0.32
	Spr-13	0.191	0	0.798	0.1	0.069	0	11.6	1.74
	Aut-13	0.195	0.1	0.772	0.1	0.068	0.01	12	1.65
BC1750	**Spr-12**	0.084	0	0.735	0	0.107	0	6.9	0.06
	Aut-12	0.054	0	0.783	0.1	0.111	0.01	7.22	1.55
	Spr-13	0.109	0	0.861	0	0.072	0	12.1	0.72
	Aut-13	0.129	0	0.829	0	0.087	0	9.71	0.36
BC2000	**Spr-12**	0.063	0.1	0.672	0	0.1	0	6.73	0.21
	Aut-12	0.057	0	0.836	0.1	0.092	0	9.06	1.18
	Spr-13	–	–	–	–	–	–	–	–
	Aut-13	0.262	0.2	0.765	0	0.082	0	9.4	0.2
OS500	**Spr-13**	0.094	0.1	0.66	0	0.07	0	9.88	0.85
OS900	**Spr-13**	0.023	0	0.9	0	0.09	0	9.58	0
OS1500	**Aut-12**	0.01	0	0.62	0	0.09	0	7.15	0.09
	Spr-12	0.027	0	0.77	0	0.07	0	10.5	0.18
OS1750	**Spr-12**	0.271	0.4	0.59	0	0.09	0	6.87	0.01
	Aut-12	0	0	0.61	0	0.09	0	7.23	0.3
	Spr-13	0.025	0	0.7	0	0.07	0	10.1	0
	Aut-13	0.066	0	0.66	0	0.08	0	8.6	0
OS2000	**Spr-12**	0	0	0.653	0.1	0.09	0.01	6.73	1.46
	Aut-12	0.016	0	0.61	0.4	0.09	0	6.88	0.32

1068 **Table 3. Results from univariate and multivariate PERMANOVA two-way**
1069 **analyses for differences in sedimentary abiotic variables.** Test for locations (Lo:
1070 Canyon and Slope); water depth (WD) and interaction term. TN: total nitrogen
1071 concentration; C:N: molar carbon/nitrogen ratio; OC: organic carbon concentration;
1072 Chl-*a*: chlorophyll *a*; CPE: chloroplastic pigment equivalents; Chl-*a*:phaeo: chlorophyll
1073 a: phaeopigments ratio. Data was normalised; resemblance was calculated using
1074 Euclidean Distance. Bold values indicate significant differences at $p < 0.05$, bold italic
1075 values indicate significant differences at $p < 0.01$.

Source	df	Mean grain size	TN	C:N	OC	CPE	Chl-a	Chl-a: phaeo
Lo	1	0.3014	**0.0245**	0.794	***0.0001***	***0.0022***	**0.0416**	0.7895
WD	4	***0.004***	0.4368	0.4526	***0.005***	***0.0002***	***0.0001***	0.4589
Lo x WD	4	***0.0008***	**0.0269**	0.4067	***0.0096***	**0.0347**	0.5768	0.4216
Res	66							
Total	76							

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Table 4. Univariate and multivariate PERMANOVA two-way analyses for environmental data in the slope and canyon systems, Test for sampling periods (Tm: Spring 2012, autumn 2012, spring 2013 and autumn 2013); water depth (WD) and interaction terms, TN: total nitrogen concentration; C:N: molar carbon/nitrogen ratio; OC: organic carbon concentration; Chl-*a*: chlorophyll *a*; CPE: chloroplastic pigment equivalents; Chl-*a*:phaeo: chlorophyll *a* divided by its degradation products (phaeopygments) indicating "freshness" of the phytodetrital OM, Data was normalised; resemblance was calculated using Euclidean Distance, Bold values indicate significant differences at p < 0.05, bold italic values indicate significant differences at p < 0.01

Source	df	Mean grain size	TN	OC	C:N	CPE	Chl-*a*	Chl-*a*: phaeo
Slope								
Tm	3	0.1409	**0.0146**	***0.0018***	***0.0003***	0.589	0.0645	0.1785
WD	3	**0.0149**	**0.0262**	**0.0408**	0.9999	**0.0446**	**0.0417**	0.7391
Tm x WD	2	0.1184	0.4582	0.7418	0.5727	0.2603	**0.015**	0.6779
Res	10							
Total	17							
Canyon								
Tm	3	***0.001***	***0.0001***	***0.0001***	***0.0001***	0.4549	***0.0002***	0.0001
WD	5	***0.0003***	***0.0028***	***0.0006***	0.2479	**0.0162**	***0.001***	***0.0001***
Tm x WD	13	0.0844	***0.0099***	0.1304	0.0938	0.1099	0.3101	***0.0001***
Res	35							
Total	56							

1129 **Table 5.** Results of PERMANOVA two-way analyses for differences in univariate
1130 (density) and multivariate (composition) meiofauna descriptors among locations (Lo:
1131 canyon and slope), water depth (WD) and interaction item, ECV: estimated component
1132 of variation. Noted that the numbers of collected samples were not equal in each
1133 location, resulting different degrees of freedom (df) for interaction terms, Information
1134 about missing samples is reported in Table 1. *: Monte Carlo inferred values
1135 (PERMANOVA permutations <100).

TOTAL		Density			Community		
Source	df	P(perm)	perms	ECV	P(perm)	perms	ECV
Lo	1	*0.0048*	9816	14186	*0.0015*	9950	44.254
WD	5	*0.0002*	9952	19683	*0.0001*	9903	76.817
LoxWD	4	0.2167	9960	3203	**0.0263**	9902	34.775
Res	66			37.75			228.71
Total	76						
Spring 2012							
Lo	1	**0.0301**	257	30374	**0.0395**	270	203.41
WD	1	0.2523	269	0.1619	0.1971	270	22.417
LoxWD	1	**0.056**	269	3.32	0.7886	270	47.525
Res	4			0.74108			151.7
Total	7						
Autumn 2012							
Lo	1	*0.0001*	9833	51798	*0.0082*	9965	65.749
WD	2	0.0165	9964	12271	**0.0125**	9942	66.353
LoxWD	2	*0.0056*	9966	35035	0.1453	9948	52.148
Res	12			13829			224.41
Total	17						
Spring 2013							
Lo	1	0.1099	9945	13076	**0.0551**	9949	48.16
WD	3	0.476	9941	-1,0705	0.1405	9932	33.898
LoxWD	3	0.9418	9961	-4.5482	0.4453	9913	3.5567
Res	10			6.4624			224.88
Total	17						
Autumn 2012							
Lo	1	0.722	4*	-28.614	0.6623	4*	-28.614
Res	2			44.914			44.914
Total	3						

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Table 6. Univariate and multivariate PERMANOVA two-way analyses for meiofauna density and composition data in the slope and Blanes canyon, Test for sampling periods (Tm: Spring 2012, autumn 2012, spring 2013 and autumn 2013); water depth (WD) and interaction terms, Bold values indicate significant differences at $p < 0.05$, bold italic values indicate significant differences at $p < 0.01$

Slope		Density			Community		
Source	df	P(perm)	perms	ECV	P(perm)	perms	ECV
Time	3	0.2364	9949	0.58963	0.0617	9919	34.462
WD	2	***0.0006***	9949	14.902	***0.003***	9937	88.6
Tm x WD	2	0.0602	9959	49.737	0.2846	9933	17.488
Res	10			40.131			
Total	17						
Canyon		Density			Community		
Source	df	P(perm)	perms	ECV	P(perm)	perms	ECV
Time	3	**0.0234**	9957	66.955	**0.0119**	9918	18.466
WD	5	**0.0271**	9951	609712	***0.0001***	9994	77.238
Tm x WD	13	**0.0203**	9938	18.078	0.0602	9894	32.565
Res	33			31.739			192.63
Total	54						

1173 **Table 7. Relative abundance of meiofaunal taxa and total density per sampling**

1174 **period and station.** BC: Blanes canyon, OS: open slope; Std: standard deviation; S:

1175 number of taxa.

Time	Spring 2012							
Station	BC500	BC900	BC1200	BC1500	BC1750	BC2000	OS1750	OS2000
Relative abundance (%)								
Amphipoda	-	-	-	-	-	-	-	-
Aplacophora	-	-	-	-	-	-	-	-
Bivalvia	-	-	0.21	0.09	0.15	0.37	-	-
Cnidaria	-	-	-	-	-	-	-	-
Cumacea	-	-	-	-	-	-	-	-
Gastrotrycha	-	-	-	-	0.15	0.09	-	-
Halacaroidea	-	0.13	0.05	-	-	-	0.19	0.16
Holoturoidea	-	-	-	-	-	-	-	-
Copepoda	1.77	11.39	3.92	1.96	4.50	4.32	6.56	4.06
Isopoda	0.12	0.13	-	0.04	0.45	0.28	0.19	-
Kinorrhynca	0.50	0.79	0.21	0.14	0.22	0.18	-	-
Loricifera	-	-	-	-	-	0.01	-	-
Nauplii	1.73	4.9	2.88	1.62	2.78	3.85	5.79	3.89
Nematoda	93.94	79.21	89.51	94.42	90.55	88.53	84.94	89.49
Nemertea	-	-	-	-	-	-	-	-
Oligochaeta	-	-	-	-	-	-	-	-
Ostracoda	0.04	-	0.27	0.09	-	-	-	-
Polychaeta	1.86	3.31	2.77	1.38	1.05	1.03	1.73	1.86
Rotifera	0.04	-	-	0.23	0.15	-	0.57	0.16
Sipunculida	-	-	-	-	-	-	-	-
Tanaidiacea	-	-	-	-	-	-	-	-
Tardigrada	-	0.13	0.16	-	-	1.22	-	0.33
Total (ind. 10 cm^{-2})	**1212.5**	**377.5**	**919.5**	**1048**	**666.5**	**532**	**259**	**295**
Std	**122.4**	**69.2**	**52.1**	**111.9**	**166.4**	**104.3**	**35.3**	**32.2**
S	**8**	**8**	**9**	**9**	**9**	**10**	**7**	**7**

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1186 **Table 7:** *continued*

Time	Autumn 2012								
Station	**BC500**	**BC900**	**BC1200**	**BC1500**	**BC1750**	**BC2000**	**OS1500**	**OS1750**	**OS2000**
Relative abundance (%)									
Amphipoda	0.02	-	-	-	-	-	-	-	-
Aplacophora	-	-	-	-	-	-	-	-	-
Bivalvia	0.19	0.47	0.26	0.53	0.05	0.09	0.14	0.18	0.13
Cnidaria	-	0.03	-	-	-	-	0.04	-	-
Cumacea	-	0.07	-	-	-	-	-	-	-
Gastrotrycha	-	-	-	-	-	-	-	0.08	-
Halacaroidea	-	0.03	0.03	0.09	0.05	-	0.04	-	-
Holoturoidea	-	-	-	-	-	-	-	-	-
Copepoda	1.99	4.99	2.12	1.62	2.86	2.32	3.54	5.57	3.25
Isopoda	0.05	-	-	0.04	0.09	-	0.09	0.04	-
Kinorrhynca	0.13	0.74	0.93	0.17	0.09	-	0.09	0.08	0.13
Loricifera	-	-	-	-	-	-	-	-	-
Nauplii	2.69	3.73	1.21	0.9	2.47	1.2	2.22	3.41	2.07
Nematoda	91.55	87.44	93.03	94.96	92.49	95.07	93.49	89.67	93.22
Nemertea	0.05	-	-	-	-	-	-	-	-
Oligochaeta		-	0.07	-	-	-	0.04	-	0.26
Ostracoda	0.08	0.07	0.07	0.04	0.09	0.09	0.28	0.08	0.88
Polychaeta	1.9	1.78	1.99	1.35	0.84	0.51	0.56	0.9	0.15
Rotifera	0.11	0.07	0.20	0.17	0.21	0.38	0.18	0.35	0.57
Sipunculida	-	0.15	-	-	-	-	-	-	-
Tanaidiacea	-	0.03	0.07	0.04	-	-	-	0.04	-
Tardigrada	-	0.30	-	0.04	0.07	0.33	0.18	0.61	0.88
Total (ind. 10 cm^{-2})	**1763**	**841**	**990.3**	**741.3**	**1389.3**	**777.3**	**704.6**	**371.3**	**225.3**
Std	**244.6**	**280.8**	**831.5**	**132.6**	**64.7**	**461.9**	**68.2**	**107.6**	**66.5**
S	**11**	**14**	**11**	**12**	**11**	**8**	**13**	**12**	**10**

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1199 **Table 7:** *continued*

Time	Spring 2013								
Station	**BC500**	**BC900**	**BC1200**	**BC1500**	**BC1750**	**OS500**	**OS900**	**OS1500**	**OS1750**
Relative abundance (%)									
Amphipoda	-	0.02	-	-	-	-	-	-	-
Aplacophora	-	-	-	0.02	-	-	-	-	-
Bivalvia	0.07	0.23	0.12	0.12	0.25	0.16	0.42	0.04	-
Cnidaria	-	-	-	-	-	-	-	-	-
Cumacea	-	-	-	-	0.02	-	-	-	-
Gastrotrycha	-	0.16	0.04	-	-	0.06	0.10	-	1
Halacaroidea	-	0.09	0.01	-	0.02	0.06	-	0.04	-
Holoturoidea	-	-		-	-	-	-	-	-
Copepoda	1.16	5.14	1.58	0.68	2.05	2.43	1.27	2.77	4.59
Isopoda	-	0.05		0.02	0.21	-	-	0.04	-
Kinorrhynca	0.46	0.79	0.55	0.02	0.12	0.41	0.73	0.19	0.36
Loricifera	-	-	-	-	-	-	-	-	-
Nauplii	1.09	4.73	2.46	0.78	1.59	5.48	3.79	3.36	4.39
Nematoda	94.88	86.07	93.71	97.65	94.32	89.25	91.35	92.38	88.22
Nemertea	-	-		-	-	-	-	-	-
Oligochaeta	-	-	0.04	-	0.02	-	-	-	-
Ostracoda	-	0.25	0.01	-	-	0.22	0.31	0.19	2
Polychaeta	2.17	1.78	1.34	0.59	0.90	1.19	0.94	0.74	0.99
Rotifera	0.15	0.07	0.01	0.02	0.09	0.19	0.21	0.10	0.79
Sipunculida	-	-	-	-	-	-	-	-	-
Tanaidiacea	-	0.02	0.04	-	-	0.12	0.31	-	-
Tardigrada	-	0.54	0.04	0.02	0.40	0.36	0.52	0.10	-
Total (ind. 10 cm^{-2})	**1289**	**1387.6**	**1663.3**	**1022.7**	**1069**	**1027**	**948**	**674**	**501**
Std	**-**	**785.1**	**671.9**	**335.8**	**499.1**	**72**	**-**	**117.1**	**-**
S	**7**	**14**	**13**	**10**	**12**	**12**	**11**	**11**	**8**

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1212   **Table 7:** *continued*

Time	Autumn 2013					
Station	BC500	BC900	BC1500	BC1750	BC2000	OS1750
Relative abundance (%)						
Amphipoda	-	-	-	-	-	-
Aplacophora	-	-	-	-	-	-
Bivalvia	0.22	0.22	0.26	0.17	-	-
Cnidaria	-	-	-	-	-	-
Cumacea	0.07	-	-	-	-	
Gastrotrycha	0.03	0.06	0.03	-		-
Halacaroidea	-	-	-	-	-	-
Holoturoidea	-	-	-	-	-	-
Copepoda	4.41	3.99	1.39	2.00	2.01	4.54
Isopoda	0.19	0.04	0.03	0.17	-	-
Kinorrhynca	0.94	0.70	0.03	0.05	-	-
Loricifera	-	-	-	-	-	-
Nauplii	0.65	3.00	0.87	1.59	1.80	2.47
Nematoda	89.85	90.19	96.35	94.32	95.19	90.09
Nemertea	-	-	-	-	-	-
Oligochaeta	-	-	-	-	-	-
Ostracoda	0.45	0.01	-	0.05	-	-
Polychaeta	3.12	1.34	0.82	0.90	0.53	1.03
Rotifera	-	-	0.03	0.11	-	-
Sipunculida	-	-	-	-	0.06	-
Tanaidiacea	-	-	-	-	-	-
Tardigrada	0.03	0.32	0.13	-	-	1.03
Total (ind. 10 cm^{-2})	877	1613.3	768	588	748	484
Std	25.5	487.6	195.6	318	9.8	-
S	11	10	10	10	4	5

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Table 8. Spearman correlation between environmental variables and meiofauna density for canyon and slope systems. Bold values indicate significant differences at p < 0.05, bold italic values indicate significant differences at p < 0.01.

Environmental variables	Meiofauna density	
	Canyon	Slope
CPE	*0,438*	*0,569*
Chl-*a*	*0,474*	**0,541**
Chl-*a*:phaeo	-0,059	**0,474**
OC	*0,367*	*0,591*
TN	0,013	**-0,465**
C:N	0,210	0,591
Clay	-0,253	*-0,600*
Silt	-0,201	0,147
Sand	**0,297**	-0,108

Table 9: Comparison of mean meiofaunal densities with depths in different submarine canyon areas (Iberian and Western Mediterranean coasts).

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Location	Canyon	Depth-range (m)	Meiofauna (ind. 10 cm-2)	Source
NW Mediterranean	Cassidaigne	245-810	245-801	Vivier (1978)
NW Mediterranean	Gulf of Lions (several)	672-2300	36-1005	De Bovée (1990)
NW Mediterranean	Gulf of Lions (several)	830-1380	530-1290	Grémare et al. (2002)
NW Mediterranean	Lacaze-Duthiers	600-1300	836-1050	Danovaro et al. (1999)
NW Mediterranean	Lacaze-Duthiers	434-1497	205-1391	Bianchelli et al. (2010)
NW Mediterranean	Cap de Creus	960-1874	147-597	Bianchelli et al. (2010)
NW Mediterranean	Blanes	400-1600	25-1500	Romano et al. (2013)
NW Mediterranean	Blanes	500-2000	209-1763	Present study
Western Mediterranean	Buscarró	600-800	40-123	Rumolo et al. (2015)
Atlantic	Cascais	445-2100	492-900	Bianchelli et al. (2010)
Atlantic	Nazaré	332-1121	9.9-236.5	Garcia et al. (2007)
Atlantic	Nazaré	458-897	747-1484	Bianchelli et al. (2010)

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Figure 1. Map of the study area showing the sampling stations and the fishing effort (hours/km^2). BC: Blanes canyon, OS: Western open slope.

Figure 2. Bathymetric patterns of each environmental variable selected. Continuous and dashed lines are the significant regression (p< 0.05) for canyon and slope samples respectively.

Figure 3. Principal component analysis (PCA) ordination based on 9 environmental variables selected. A) Canyon vs slope. B) Canyon.

Figure 4. Bathymetric scatter plot of meiofaunal densities. Dashed line represent significant regression (p<0.05) for slope samples.

Figure 5. Temporal fluctuations of meiofaunal density within the A) Blanes canyon and B) Slope.

Figure 6. MDS based on meiofaunal community composition in the Blanes canyon and at the western slope for each sampling period (based on Bray Curtis similarity values of four-root transformed data). A) Spring 2012. B) Autumn 2012. C) Spring 2013. D) Autumn 2013.

Figure 7. Temporal variation of ancillary data in the study area. A) Chlorophyll-a concentration /surface productivity. B) Temporal variation of high waves in the study area. Lines indicate monthly average (blue), monthly max (red) and hourly data (green). C) Monthly discharge of the Tordera river measured at the gauging nearest station to river mouth (data from Agència Catalana de l´Aigua, ACA).

SUPPLEMENTARY MATERIAL

Table S1. Results of the two-way PERMANOVA pair-wise test (Factor "Time" with 4

levels (spring, autumn 2012, spring, autumn 2013), factor "WD ": Water Depth, with 6

levels (500, 900, 1200, 1500, 1750 and 2000 m)) for meiofauna density. Data was

square-root transform and resemblance was calculated using Euclidean Distance prior to

analysis, Bold values indicate significant differences at $p < 0.05$, bold italic indicate

significant at $p < 0.01$.

Table S2. Results from pair-wise multivariate PERMANOVA analyses for

differences in meiofauna composition. PERMANOVA pair-wise comparisons

between Time and water depth (WD). Spr: spring; Aut: autumn. Data was fourth-root

transform and resemblance was calculated using Bray Curtis prior to analysis. Bold

values indicate significant differences at $p < 0.05$ and bold italic indicate significant at p

< 0.01.

Table S3. **Distance-based linear model (DISTLM) for meiofauna assemblages and**

selected environmental variables for the western open slope. Variables: Selected

environmental variables used to calculate the optimum model. Marginal tests:

explanation of variation for each variable taken separately. Sequential tests: conditional

tests of individual variables in constructing the model. Each test examines whether

adding the variable contributes significantly to the explained variation. Selection

procedure: step-wise, selection criterion: adjusted R^2. Prop.: % variation explained.

Cumul.: cumulative variation explained. Chl-a: chlorophyll a, CPE: chloroplastic

pigment equivalents, Chl-a:phaeo: chlorophyll a divided by its degradation products

indicating 'freshness' of the phytodetrital OM, TN: total nitrogen content, OC: organic

carbon content, C:N: molar carbon-nitrogen ratio.

Table S4. Distance-based linear model (DISTLM) for meiofauna assemblages and

selected environmental variables for the Blanes Canyon. Variables: Selected

environmental variables used to calculate the optimum model. Marginal tests:

explanation of variation for each variable taken separately. Sequential tests: conditional

tests of individual variables in constructing the model. Each test examines whether

adding the variable contributes significantly to the explained variation. Selection

procedure: step-wise, selection criterion: adjusted R^2. Prop.: % variation explained.

1348 Cumul.: cumulative variation explained. Chl-a: chlorophyll a, CPE: chloroplastic
1349 pigment equivalents, Chl-a:phaeo: chlorophyll a divided by its degradation products
1350 indicating 'freshness' of the phytodetrital OM, TN: total nitrogen content, OC: organic
1351 carbon content, C:N: molar carbon-nitrogen ratio.
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