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## Contribution to the study of deep coastal detritic bottoms: the algal communities of the continental shelf off the Balearic Islands, Western Mediterranean

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### Abstract

Three main algal-dominated coastal detritic communities from the continental shelf off Mallorca and Menorca (Balearic Islands, Western Mediterranean) are described herein: maërl beds dominated by *Spongites fruticosus* and forests of *Laminaria rodriguezii* located in the Menorca channel, and *Peyssonnelia inamoena* beds found along the Southern coast of Menorca. There seems to be a gradient of disturbance from the highly disturbed *Peyssonnelia* beds to the almost undisturbed *L. rodriguezii* forests. Whether this gradient is the result of current and past anthropogenic pressure (e.g. trawling intensity) or is driven by natural environmental factors needs further assessment. Finally, the location of the target communities by means of ROV dives combined with the use of a Box-Corer dredge and beam trawl proved to be a good methodology in the study of the composition and structure of these deep water detritic communities.

**Keywords:** detritic bottoms, *Laminaria rodriguezii*, macroalgae, sampling methods, Mediterranean Sea, *Peyssonnelia inamoena*, *Spongites fruticosus*.

### Introduction

Mediterranean algal-dominated coastal detritic bottoms usually develop at depths between 25 and 130 m (Pérès, 1985; Giaccone *et al.*, 1994). They are composed of silt, sand, gravels, and calcareous skeletons of benthic organisms such as molluscs, bryozoans, cnidarians, echinoderms and macroalgae. Free-living members of the orders Corallinales and Peyssonneliales (Pérès, 1985; Klein & Verlaque, 2009) are usually the major components of these bottoms. Both the skeletons and the calcareous algae allow the settlement and growth of organisms usually found on rocky bottoms (Bianchi, 2001), creating a special habitat harbouring animals and plants of both soft and hard bottoms (Laborel, 1987).

Different assemblages have been recognized in Mediterranean algal-dominated coastal detritic bottoms, each one characterized by either one or a reduced number of more or less exclusive species (e.g. see Dieuzede, 1940; Huvé, 1954, 1956; Jacquotte, 1962; Pérès & Picard, 1964; Picard, 1965; Giaccone, 1967; Bourcier, 1968; Augier & Boudouresque, 1978; Ballesteros, 1988, 1994; Giaccone *et al.*, 1994). The Balearic Islands harbour extensive areas of these kinds of bottoms and different seascapes have been described between 52 and 93 m, using bottom trawls (Joher *et al.*, 2012): maërl beds dominated

by *Spongites fruticosus*, deep water forests of *Laminaria rodriguezii*, two types of *Peyssonnelia* beds (one dominated by *P. inamoena* and the other one by *P. rubra*, both species presenting hypobasal calcification, and the last one presenting some cystolists too), and red algae meadows dominated by *Osmundaria volubilis* and *Phyllophora crispa*.

However, although bottom trawling was effective for the characterization of underwater landscapes, descriptions at community level require the use of smaller sampling areas. Several ROV dives were performed in 2009 in the Menorca channel and along the Southern coast of Menorca (Barberá *et al.*, 2009, 2012) in order to locate certain homogeneous areas harbouring the communities that characterized the seascapes found by Joher *et al.* (2012). Three of these areas were located: one with maërl beds of *S. fruticosus*, another with forests of *L. rodriguezii*, and a last one with *P. inamoena* beds. In contrast, extensive areas covered by the assemblage dominated by *Osmundaria volubilis* and *Phyllophora crispa* were found, with a patchy distribution.

Maërl beds dominated by *S. fruticosus* have seldom been reported from the Balearic Islands (Barberá *et al.*, 2012), and their composition and structure have only been studied from Tossa de Mar (Northwestern Mediterranean, Spain) (Ballesteros, 1988), where the maërl bed

grows in reduced light levels (around 0.3 % of surface PAR irradiance) and moderate temperature range conditions (12.5 to 21.5°C). Forests of *L. rodriguezii* develop under low light intensities (usually at depths between 50 and 120 m, being more abundant below 70 m), low temperature (less than 14°C), and unidirectional current conditions (Feldmann, 1934; Huvé, 1955; Molinier, 1960; Pérès & Picard, 1964; Giaccone, 1967, 1971; Lüning, 1990; Giaccone & Di Martino, 1997). Most information available about these rarefied kelp forests focuses on species composition although there are no quantified lists of species (Huvé, 1955; Molinier, 1956; Gautier & Picard, 1957). Finally, several authors have reported *Peyssonnelia* beds developing on circalittoral bottoms, mainly along the coasts of Marseille, the Tyrrhenian Sea and the Balearic Islands (e.g. Huvé, 1954; Carpine, 1958; Parenzan, 1960; Augier & Boudouresque, 1978; Basso, 1990; Ballesteros, 1994; Joher *et al.*, 2012), highlighting the variety of the dominant *Peyssonnelia* species. These beds also develop under low light conditions but they seem to need pulsing current conditions, which prevent the burial of living *Peyssonnelia* spp. (Bourcier, 1968; Basso, 1990). Two kinds of *Peyssonnelia* beds, one dominated by *P. rosa-marina* and the other by an unidentified *Peyssonnelia* have been reported previously from the Balearic Islands (Ballesteros, 1994), but there is no published information on the beds dominated by *P. inamoena*.

The purpose of this paper is to describe the species composition and abundance of three specific communities from the detritic bottoms off the Balearic Islands (*S. fruticosus*, *L. rodriguezii* and *P. inamoena*), which characterized three of the landscapes described previously in Joher *et al.* (2012). Another objective was to check whether Box-Corer dredging and beam trawling, combined with ROV images, are suitable methodologies to characterize deep-water coastal detritic communities.

## Materials and Methods

The sampling area was located in the Menorca channel and along the Southern coast of Menorca (the Balearic Islands, Western Mediterranean; Fig. 1). The continental shelf bottoms of this area are characterized by sediments of biogenic origin (Canals & Ballesteros, 1997; Fornós & Ahr, 1997) with a high percentage of carbonates (Acosta *et al.*, 2002), and the water column presents a high light transmittance (Ballesteros & Zabala, 1993; Canals & Ballesteros, 1997).

Sampling was performed in May 2009, during the MEDITS\_ES05\_09 campaign organized by the Centre Oceanogràfic de Balears (Instituto Español de Oceanografía). Target communities had been located previously by ROV during the CANAL0209 research survey (February-March 2009): large areas were occupied by the communities with *Spongites fruticosus* and *Laminaria rodriguezii* in the Menorca channel at depths be-

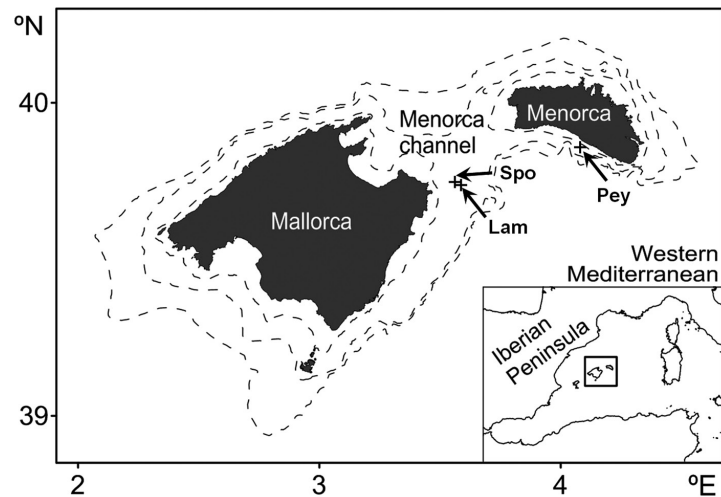
tween 50 and 62 m, while the community dominated by *Peyssonnelia inamoena* was found on the Southern coast of Menorca, at depths of around 65 m.

Because of the deep-water distribution of these communities, we did not sample them by SCUBA diving but used other sampling methods: dredges (e.g. see Dieuzede, 1940; Huvé, 1956; Costa, 1960; Bourcier, 1968; Blunden *et al.*, 1977; Bordehore *et al.*, 2003; Peña, 2010) and beam trawls (Barberá *et al.*, 2012; Ellis *et al.*, 2013). Images obtained by ROV, together with previous results (Joher *et al.*, 2012), showed that the community dominated by *S. fruticosus* was very homogeneous, and composed mainly of small maërl-forming species (*S. fruticosus* and *Phymatolithon calcareum*). There, samples were collected using a Box-Corer dredge (sampling area: 200 cm<sup>2</sup>). In contrast, communities with *L. rodriguezii* and *P. inamoena* were more heterogeneous because of the size of the algae and the aggregation in clusters of the thalli of the characteristic species. There, the use of a Box-Core was disregarded, and samples were collected using a beam trawl (horizontal and vertical openings: 1.30 and 0.88 m, respectively; mesh size: 10 mm), at speeds of 2.5-3.0 knots. Trawling time ranged from 5 to 12 seconds and was controlled by a SCANMAR system (Scanmar Maritime Services Inc., Makati City, Philippines) in order to calculate the trawled area, which ranged from 6 to 16 m<sup>2</sup>.

We collected seven samples of the *S. fruticosus* community, which were integrally quantified, and two from the *L. rodriguezii* and *P. inamoena* communities. All samples were preserved on board in 4% formalin:seawater. Samples of *L. rodriguezii* and *P. inamoena* were homogeneously extended occupying the corresponding sampled surface, and we took two replicates of 1.2x1.2 m<sup>2</sup> per sample. Samples and replicates were named *C s-r*, where *C* corresponds to each community, *s* to each sample, and *r* to each replicate. Then, they were sorted and identified to the minimum taxonomic level, and each taxon was quantified measuring its algal surface ( $S_{a_i}$ , in cm<sup>2</sup>) and biomass ( $B_i$ , as dry weight in g) (Ballesteros, 1992). Skeletons of dead Corallinales were rejected because we only wanted to quantify live specimens.

Several synthetic parameters were calculated for each sample/replicate: a) the number of species, total algal surface ( $S_{a_T}$ ) and total biomass ( $B_T$ ); b) the Index of Floral Originality (IFO =  $(\sum 1/M_i)/n$ ), where  $M_i$  is the number of samples in which the species *i* occurred and *n* the number of species in the sample; c) the total algal surface and biomass of the maërl-forming species ( $MFS_{sa}$ ,  $MFS_{sb}$ ); d) Shannon's diversity index ( $H' = -\sum p_i \log_2 p_i$ ), where  $p_i$  corresponds to the proportion of the measured parameter ( $S_{a_i}/S_{a_T}$  or  $B_i/B_T$ ) for each species; and e) Pielou's evenness index ( $J' = H'/\log_2 S$ ), where  $H'$  was based both on algal surface and biomass.

In order to verify the grouping of the samples, cluster analysis accompanied by the SIMPROF test (Clarke *et*



**Fig. 1:** Sampling locations of the three communities studied in the Menorca Channel and the Southern coast of Menorca. Isobaths of -50, -100 and -200 m are shown. Abbreviations: Spo, *Spongites fruticulosus* beds; Lam, forests of *Laminaria rodriguezii*; Pey, *Peyssonnelia inamoena* beds.

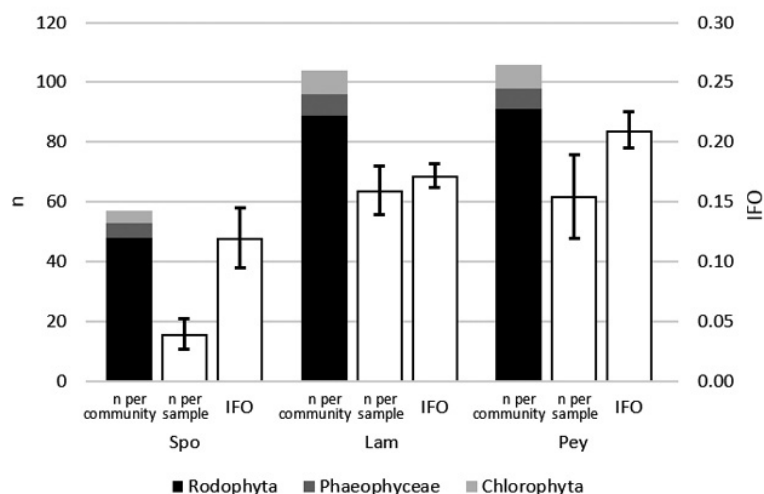
*al.*, 2008) adjusted to 9999 permutations and a 0.1% significance level according to Potter *et al.* (2001), based on Sørensen and Bray-Curtis similarity matrices, were performed for each community. Finally, SIMPER tests were used to calculate species contribution to the similarities within each of the three studied communities and their characteristic species. These analyses were performed with PRIMER version 6 software (Clarke & Warwick, 2001).

## Results

We identified up to 143 algal taxa at specific and infraspecific level (below named species for convenience) (Table 1), although some of them could not be identified to species level because either we had only small fragments of the specimens, they were sterile (e.g. *Agla-*

*othamnion* sp., *Peyssonnelia* sp., *Polysiphonia* sp., unidentified Rhodophyta), or they are probably undescribed species (e.g. *Halymenia* sp., *Rhodymenia* sp.).

A total of 57 algal species were identified on the *Spongites fruticulosus* beds (Table 2), with a dominance (84.2%) of Rhodophyta (Fig. 2). The number of species per sample was  $16 \pm 5$ ; the  $Sa_T$  per sample  $3965 \pm 2838$  cm<sup>2</sup> m<sup>-2</sup>; and the  $B_T$  per sample  $351 \pm 270$  g dw m<sup>-2</sup>. Maërl-forming species represented  $76.8 \pm 21.5\%$  of total  $Sa_T$  per sample, and  $94.5 \pm 3.7\%$  of  $B_T$  (Fig. 3). The characteristic species of these maërl beds were *S. fruticulosus* and *Phymatolithon calcareum* (SIMPER test, Fig. 4), which accounted for 80% of  $Sa_T$  and 82.6% of  $B_T$ . It should be noted that despite statistical analyses (cluster + SIMPROF), based both on qualitative and algal surface data, indicated that the samples belonged to a single significant group;



**Fig. 2:** Number of species (n) per community showing Rhodophyta, Phaeophyceae and Chlorophyta, and number of species and Index of Floral Originality (IFO) per sample (mean and standard deviation). Abbreviations: Spo, *Spongites fruticulosus* beds; Lam, *Laminaria rodriguezii* forests; Pey, *Peyssonnelia inamoena* beds.

**Table 1.** Species composition of the collected samples/replicates. For each taxon, the upper value corresponds to the algal surface (Sa, in cm<sup>2</sup> m<sup>-2</sup>) in the sample or replicate, and the lower value, the biomass as dry weight (B, in g dw m<sup>-2</sup>). The introduced species are marked with an asterisk (\*), and the maërl-forming species, with a hashtag (#). Abbreviations: Spo, *Spongites fruticosus* beds; Lam, *Laminaria rodriguezii* forests; Pey, *Peyssonnelia inamoena* beds; MC, Menorca Channel; SM, Southern Menorca.

Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2					
	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	SM	SM	SM	SM	SM	SM	SM	SM				
<i>Acrochaetium</i> sp.									10.0							0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1			
<i>Acrosorium ciliolatum</i> (Harvey) Kylin									0.100							0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
<i>'Acrosymphytonema bremaniae'</i> (stadium) Boudouresque, Perret-Boudouresque & Knoepffler-Peguy <i>nom. inval.</i>																																		
<i>Acrothamnion preissii</i> (Sonder) E.M. Wollaston*																																		
<i>Aglaothamnion tenuissimum</i> (Bonnemaison) Feldmann-Mazoyer									5.0							2.8	5.2	2.8	2.8	2.8	2.8	3.3	7.2	5.4	1.7	2.0	0.016							
<i>Aglaothamnion tripinnatum</i> (C. Agardh) Feldmann-Mazoyer								0.050								0.028	0.031	0.028	0.022	0.022	0.022	0.036	0.021	0.007	0.016									
<i>Aglaothamnion</i> sp.																																		
<i>Anthamnion</i> sp.									5.0																									
<i>Apoglossum ruscifolium</i> (Turner) J. Agardh								0.050																										
<i>Bonnemaisonia asparagoides</i> (Woodward) C. Agardh																																		
<i>Bonnemaisonia</i> sp.																																		
<i>Botryocladia botryoides</i> (Wulfen) Feldmann																																		

(continued)



Table 1 (continued)

Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2			
	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-61	MC	-61	MC	-62	MC	-62	SM	-64	SM	-64	SM	-65	SM	-65		
<i>Botryocladia chiajeana</i> (Meneghini) Kylin																0.4	0.6	0.3					0.3	0.5								
<i>Brongniartella byssoides</i> (Goodenough & Woodward) F. Schmitz																0.014	0.007	0.007					0.001	0.005								
<i>Callophyllis laciniata</i> (Hudson) Kützing																							0.1	0.8								
<i>Ceramium bertholdii</i> Funk										5.0						0.1								0.004	0.023					0.1		
<i>Ceramium codii</i> (H. Richards) Mazoyer										0.050						0.001															0.001	
<i>Champia parvula</i> (C. Agardh) Harvey																	0.2														0.1	
<i>Chrysomenia ventricosa</i> (J.V. Lamouroux) J. Agardh																	0.007														0.1	
<i>Chylocladia verticillata</i> (Lightfoot) Bliding																															0.1	
<i>Contarinia</i> <i>peyssonnelliaeformis</i> Zanardini	207.5																															0.001
<i>Cordylecladia erecta</i> (Greville) J. Agardh cf																																0.1
<i>Cryptonemia lomation</i> (Bertoloni) J. Agardh																																0.001
<i>Cryptonemia</i> <i>longiarticulata</i> Funk species inquirendum																																0.001
<i>Cryptonemia tuniformis</i> (A. Bertoloni) Zanardini	9.0																															0.5
<i>Cryptopleura ramosa</i> (Hudson) L. Newton	0.050																															0.003
<i>Dasya corymbifera</i> J. Agardh																																0.020

(continued)



Table 1 (continued)

Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2											
	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-61	MC	-61	MC	-62	MC	-62	SM	-64	SM	-64	SM	-65	SM	-65										
<i>Hydrothothon farinosum</i> (J.V. Lamouroux)																																								
D. Penrose & Y.M. Chamberlain																																								
<i>Hypoglossum</i> <i>hypoglossoides</i> (Stackhouse) F.S. Collins & Hervey																																								
<i>Irvinea boergesenii</i> (Feldmann) R.J. Wilkes, L.M. Melvor & Guiry																																								
<i>Jania virgata</i> (Zanardini) Montagne																																								
<i>Kalymenia feldmannii</i> Codomier																																								
<i>Kalymenia patens</i> (J. Agardh) Codomier ex P.G. Parkinson																																								
<i>Kalymenia requienii</i> (J. Agardh) J. Agardh																																								
<i>Kalymenia</i> sp.																																								
<i>Lejolisia mediterranea</i> Bornet																																								
<i>Leptofaucheia coralligena</i> Rodríguez-Prieto & De Clerk																																								
<i>Lithophyllum racemosum</i> (Lamarck) Foslief <sup>#</sup>																																								
<i>Lithophyllum stictaeforme</i> (Areschoug) Hauck <sup>#</sup>																																								
<i>Lithophyllum</i> sp. <sup>#</sup>																																								
<i>Lithothamnion corallioides</i> (P.L. Crouan & H.M. Crouan) P.L. Crouan & H.M. Crouan <sup>#</sup>																																								

(continued)



Table 1 (continued)

Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2													
	MC	-50-60 13/05/09	MC	-50-60 13/05/09	MC	-50-60 13/05/09	MC	-50-60 13/05/09	MC	-50-60 13/05/09	MC	-50-60 13/05/09	MC	-50-60 13/05/09	MC	-61 15/05/09	MC	-61 15/05/09	MC	-62 15/05/09	MC	-62 15/05/09	SM	-64 19/05/09	SM	-64 19/05/09	SM	-65 19/05/09	SM	-65 19/05/09	SM	-65 19/05/09										
<i>Lithothamnion valens</i>	375.0	900.0			1300.0	250.0	250.0	250.0	250.0	250.0	250.0	250.0	200.0	200.0	196.4	190.3	190.3	190.3	31.3	31.3	24.8	24.8	2.1	2.1	2.1	2.1	5.2	5.2	2.8	2.8												
<i>Lomentaria clavellosa</i> (Lightfoot ex Turner) Gailion	37.500	90.000			130.000	25.000	25.000	25.000	25.000	25.000	25.000	20.000	20.000	20.000	19.462	19.028	19.028	19.462	3.125	3.125	2.483	2.483	0.208	0.208	0.208	0.208	0.521	0.521	0.278	0.278												
<i>Lomentaria eregovicii</i> Verlaque, Boudouresque, Meinesz, Giraud & Marcot-Coquegniot																			0.8	0.8																						
<i>Lomentaria subdichotoma</i> Eregovic			20.0																				0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1							
<i>Lophosiphonia obscura</i> (C. Agardh) Falkenberg			0.120																			0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1						
<i>Melobesia membranacea</i> (Esper) J.V. Lamouroux <sup>#</sup>																						0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1					
<i>Meredithia microphylla</i> (J. Agardh) J. Agardh	25.0																					0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1				
<i>Mesophyllum alternans</i> (Foslie) Cabioch & M.L. Mendoza <sup>#</sup>	2.500																					0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
<i>Mesophyllum expansum</i> (Philippi) Cabioch & M.L. Mendoza <sup>#</sup>																						0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1			
<i>Monosporus pedicellatus</i> (Smith) Solier																						0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
<i>Myriogramme carnea</i> (J.J. Rodríguez y Femenías) Kyllin																						0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
<i>Myriogramme tristromatica</i> (J.J. Rodríguez y Femenías) Boudouresque																						0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
<i>Neogoniolithon mamillosum</i> (Hauck) Setchell & L.R. Mason <sup>#</sup>																																										
<i>Neurocaulon foliosum</i> (Meneghini) Zanardini																																										

(continued)



Table 1 (continued)

Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2			
	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-61	MC	-61	MC	-62	MC	-62	MC	SM	-64	SM	-64	SM	-65	SM	-65	
<i>Phyllophora hereditae</i> (Clemente) J. Agardh	2100.0	2475.0	50.0	550.0	155.0	2075.0	700.0	35.9	219.2	55.4	99.3	0.004	0.006	0.010	0.3	0.6	1.1	0.004	0.006	0.010	0.004	0.006	0.004	0.006	0.010	0.004	0.006	0.010	0.004	0.010		
<i>Phymatolithon calcareum</i> (Pallas) W.H. Adey & D.L. McKibbin <sup>#</sup>	210.000	247.500	5.000	55.000	15.500	207.500	70.000	3.594	21.877	5.366	9.931	0.451	0.009	0.007	0.004	0.007	0.004	0.009	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007			
<i>Plocamium cartilagineum</i> (Linnaeus) P.S. Dixon								1.4	0.3									1.4	0.8				1.4	0.8					0.9	0.4		
<i>Polysiphonia ornata</i> J. Agardh						5.0		0.021	0.014									0.009	0.007				0.009	0.007					0.004	0.002		
<i>Polysiphonia perforans</i> Cormaci, G. Furnari, Pizzuto & Serio						0.050		0.001																								
<i>Polysiphonia subulifera</i> (C. Agardh) Harvey					46.0			0.1	2.4									0.1	2.4				0.7	0.1					0.1	0.1		
<i>Polysiphonia</i> sp.					0.220			0.001	0.024									0.001	0.032				0.006	0.001					0.001	0.001		
<i>Pterothamnion crispum</i> (Ducluzeau) Nägeli					5.0			262.0	7.1									262.0	7.1				8.5	1.6					1.6	0.016		
<i>Pterothamnion plumula</i> (J. Ellis) Nägeli				5.0				2.618	0.072									2.618	0.072				0.085	0.016					0.1	0.1	0.1	
<i>Ptilocladopsis horrida</i> Berthold				0.050				0.001										0.001					0.1	0.1					0.001	0.001	0.001	
<i>Ptilothamnion pluma</i> (Dillwyn) Thuret				5.0				0.001	0.001									0.001	0.001				0.1	0.1					0.1	0.1	0.1	
<i>Ptilothamnion</i> sp.				0.050					13.8										13.8				8.5	0.1						0.1	0.001	
<i>Radicilingua thysanorhizans</i> (Holmes) Papenfuss				5.0				0.1	2.1									0.1	2.1				0.1	0.1					0.1	0.001	0.001	
<i>Radicilingua</i> sp.				0.050				0.014	0.007									0.014	0.007				0.7	0.7					0.1	0.001	0.001	
<i>Rhodophyllis divaricata</i> (Stackhouse) Papenfuss				5.0																		0.5	0.5									
<i>Rhodophyllis strafforellii</i> Ardissonne				4.5				0.014	0.007									0.014	0.007			1.6	1.6						0.9	0.7	0.7	
				0.050				0.008	0.011									0.008	0.011			0.008	0.011					0.007	0.007	0.007	0.007	

(continued)

Table 1 (continued)

Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2					
	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	SM	SM	SM	SM	SM	SM	SM	SM	SM				
<i>Rhodymenia</i> sp.	-50-60 13/05/09	-50-60 13/05/09	-50-60 13/05/09	-50-60 13/05/09	-50-60 13/05/09	-50-60 13/05/09	-50-60 13/05/09	-50-60 13/05/09	-50-60 13/05/09	-50-60 13/05/09	-61 15/05/09	-61 15/05/09	-61 15/05/09	-61 15/05/09	-61 15/05/09	-62 15/05/09	-62 15/05/09	-62 15/05/09	-62 15/05/09	-62 15/05/09	-62 15/05/09	-64 19/05/09	-64 19/05/09	-64 19/05/09	-64 19/05/09	-64 19/05/09	-64 19/05/09	-65 19/05/09	-65 19/05/09	-65 19/05/09	-65 19/05/09			
<i>Rodriguezella bornetii</i> (J.J. Rodriguez y Femenias) F. Schmitz ex J.J. Rodriguez y Femenias											0.5	0.001	0.001	0.001	0.004	0.004	0.108	0.108	0.002	0.002	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	2.0			
<i>Rodriguezella pinnata</i> (Kützing) F. Schmitz ex Falkenberg																						0.1									0.010			
<i>Rodriguezella strafforelloi</i> F. Schmitz ex J.J. Rodriguez y Femenias																									6.9					0.014				
<i>Rytiphlaea tinctoria</i> (Clemente) C. Agardh																												0.026		0.2	0.003			
<i>Sahlingia subintegra</i> (Rosenvinge) Kormann																											0.6	0.4	0.3		0.1			
<i>Sebdenia rodrigueziana</i> (Feldmann) Athanasiadis																											0.015	0.004	0.003		0.1	0.001		
<i>Sphaerococcus coronopifolius</i> Stackhouse																																2.6		
<i>Sphaerococcus rhizophylloides</i> J.J. Rodriguez y Femenias	21.0 0.095																															4.0	0.014	
<i>Spongites fruticosus</i> Kützing#	3475.0	3825.0	50.0	1500.0	585.0	850.0	850.0	1285.0	899.0	620.8	620.8	899.0	899.0	899.0	899.0	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	89.896	0.3
<i>Sylonema alsidii</i> (Zanardini) K.M. Drew																																	0.1	0.001
<i>Titanoderma pustulatum</i> (J.V. Lamouroux) Nägeli																																	0.3	
<i>Titanoderma</i> sp.																																	0.001	0.001
<i>Womersleyella setacea</i> (Hollenberg) R.E. Norris*																																	0.1	0.001

(continued)

Table 1 (continued)

Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2							
	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-61	MC	-61	MC	-62	MC	-62	MC	SM	-64	SM	-64	SM	-65	SM	-65					
Date of collection	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	15/05/09	15/05/09	15/05/09	15/05/09	15/05/09	15/05/09	15/05/09	15/05/09	15/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09						
Unidentified Ceramiaceae				0.5			4.7																													
Unidentified Corallinaceae	400.0	250.0		0.050			0.047																													
Unidentified	40.000	25.000		205.0	5.0		86.3																													
Delesseriaceae				20.500	0.050		7.010																													
Unidentified																																				
Halymeniaceae																																				
Unidentified				5.0																																
Rhodomeleaceae				0.050																																
Unidentified Rhodophyta 1																																				
Unidentified Rhodophyta 2																																				
Phaeophyceae (Ochrophyta)																																				
<i>Asperococcus bullosus</i> J.V. Lamouroux																																				
<i>Carpomitra costata</i> (Stackhouse) Batters																																				
<i>Cuiteria chilosa</i> (Falkenberg) P.C. Silva																																				
<i>Dictyopteris lucida</i> M.A. Ribera Siguán, A. Gómez Garreta, Pérez Ruzafa, Barceló Martí & Rull Lluch																																				
<i>Dictyota dichotoma</i> (Hudson) J.V. Lamouroux																																				
<i>Halopteris filicina</i> (Grateloup) Kützting																																				
<i>Laminaria rodriguezii</i> Bornet																																				

(continued)

Table 1 (continued)

Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2											
	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-50-60	MC	-61	MC	-61	MC	-62	MC	-62	SM	-64	SM	-64	SM	-65	SM	-65										
<i>Sphacelaria plumula</i> Zanardini					5.0	10.0																																		
<i>Zanardinia typus</i> (Nardo) P.C. Silva					0.050	0.100																																		
<i>Zonaria tournefortii</i> (J.V. Lamouroux) Montagne	36.0																																							
Unidentified encrusting Phaeophyceae	0.125																																							
Chlorophyta																																								
<i>Cladophora</i> sp.																																								
<i>Derbesia tenuissima</i> (Morris & De Notaris) P.L. Crouan & H.M. Crouan																																								
<i>Fiabellia petiolata</i> (Turra) Nizamuddin							725.0																																	
<i>Halimeda tuna</i> (J. Ellis & Solander) J.V. Lamouroux							3.650																																	
<i>Microdictyon umbilicatum</i> (Velley) Zanardini																																								
<i>Palmophyllum crassum</i> (Naccari) Rabenhorst																																								
<i>Pseudochlorodesmis</i> <i>furcellata</i> (Zanardini) Børgesen																																								
<i>Ulvella scutata</i> (Reinke) R. Nielsen, C.J. O'Kelly & B. Wylor																																								
<i>Umbraulva dangeardii</i> M.J. Wynne et G. Furnari																																								
<i>Uronema marinum</i> Womersley																																								
<i>Valonia macrophysa</i> Kützing																																								



sample Spo III grouped separately from the other samples in the analysis based on biomass because it presented an extremely low biomass compared to the rest of the samples.

A total of 104 species were identified in samples collected from *Laminaria rodriguezii* forests (Table 2), with Rhodophyta accounting for 85.6% of the species (Fig. 2). This community presented a mean of  $64 \pm 8$  species per replicate, a  $Sa_T$  of  $3653 \pm 817 \text{ cm}^2 \text{ m}^{-2}$  and a  $B_T$  of  $106 \pm 42 \text{ g dw m}^{-2}$  (Fig. 3). The species *Phyllophora crispa*, *Spongites fruticulosus*, *Peyssonnelia coriacea*, *Laminaria rodriguezii*, *Flabellia petiolata* and *Peyssonnelia rubra*, in this order, were found to be the main characterizing species in terms of algal surface, according to the SIMPER test (Fig. 4). Maërl-forming species represented  $21.8 \pm 5.7\%$  of  $Sa_T$  but  $76.3 \pm 5.0\%$  of  $B_T$ , and consequently, as regards biomass, the SIMPER test indicated that the main species were the Corallinales *Spongites fruticulosus*, *Phymatolithon calcareum* and *Lithothamnion valens* (Fig. 4). Statistical analyses based on both qualitative and quantitative data showed no significant differences between replicates of both samples.

A total of 106 species were identified in the community with *Peyssonnelia inamoena* (Table 2), with Rhodophyta accounting for 85.8% of the species (Fig. 2). The number of species per replicate was  $62 \pm 14$ ;  $Sa_T$  was  $1661 \pm 1118 \text{ cm}^2 \text{ m}^{-2}$ ; and  $B_T$   $34 \pm 29 \text{ g dw m}^{-2}$  (Fig. 3). While the SIMPER test for algal surface indicated that *P. inamoena* and *P. rubra* were the most characteristic species, the analysis performed with the biomass data revealed four *Peyssonnelia* species: *P. inamoena*, *P. rosa-marina*, *P. harveyana* and *P. rubra* (Fig. 4). In this community, maërl-forming species accounted for  $6.3 \pm 3.6\%$  of  $Sa_T$  and  $30.6 \pm 15.0\%$  of  $B_T$  (Fig. 3). According to the statistical analyses, replicates of both samples did not present significant differences in quantitative and qualitative species composition.

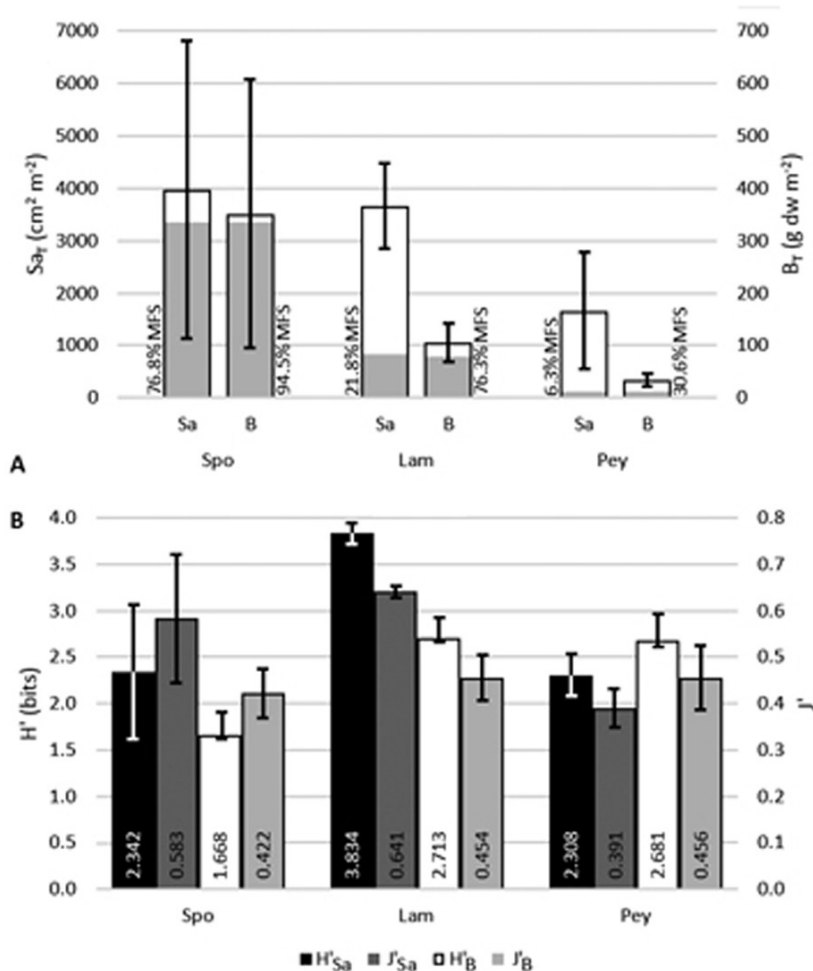
## Discussion

*Spongites fruticulosus* beds presented a very low number of species,  $H'_B$  and  $J'_B$ , which could also be a sampling artifact due to the small sampling areas. Besides, our results show that they were mostly characterized by the calcareous species of the basal stratum (mainly *Spongites fruticulosus* and *Phymatolithon calcareum*), which accounted for  $76.8 \pm 21.5\%$  of  $Sa_T$  and  $94.5 \pm 3.3\%$  of  $B_T$ , erect algae being irrelevant. This relatively low development of fleshy species was also been observed previously in Tossa de Mar (Spain, Northwestern Mediterranean) and although it might be caused by low irradiance levels (Ballesteros, 1988), we still do not have the clues to explain this situation as the other communities studied here thrive at the same irradiance levels.

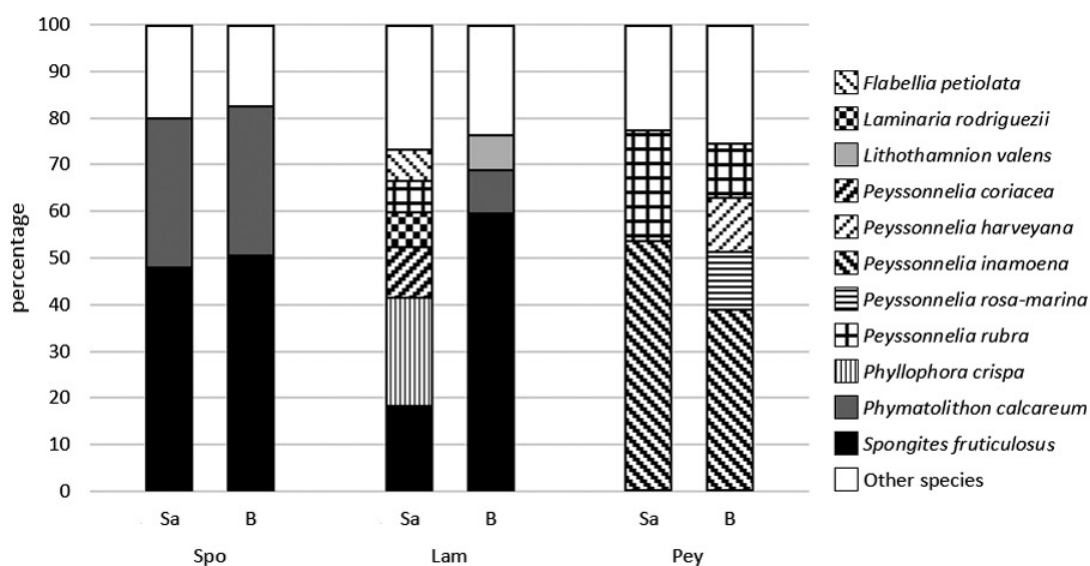
A contrasting case is displayed by the kelp forest of *Laminaria rodriguezii*, which showed a well-developed erect stratum, composed of dispersed clusters of thalli of

*L. rodriguezii*, interspersed with free-living corallines and sand patches. Free-living corallines *S. fruticulosus* and *P. calcareum* were far less abundant ( $21.8 \pm 5.7\%$  of  $Sa_T$  and  $76.3 \pm 4.9\%$  of  $B_T$ ) than on *Spongites fruticulosus* beds. As expected, the forest presented higher values of  $H'$  and  $J'$  when compared to *Spongites fruticulosus* beds (Table 2), due to higher complexity. Diversity values based on algal surface are amongst the highest in Mediterranean algal communities, and similar to those found on free-living *Peyssonnelia* beds (Ballesteros, 1994) or other deep-water communities along the Northeastern coast of Spain (*Cystoseira zosteroides*, *Halimeda tuna*, *Lithophyllum stictaeforme* and *Phymatolithon calcareum*) (Ballesteros, 1988, 1992). The kelp forest of *L. rodriguezii* studied here was very similar in species composition to that found in Hyères Islands (France, Northwestern Mediterranean) (Gautier & Picard, 1957), and even to that found growing over coralligenous concretions at Ustica (Tyrrhenian Sea, Italy) (Giaccone, 1967), suggesting a high homogeneity of these forests in the Western Mediterranean Sea.

*Peyssonnelia inamoena* beds were quite diverse because soft erect algae and prostrate species were relatively abundant. These beds were as rich in species as the *L. rodriguezii* forests but showed lower values of  $H'$  and  $J'$  (Table 2). They displayed the lowest percentage of free living corallines of the three communities ( $6.3 \pm 3.6\%$  of  $Sa_T$  and  $30.6 \pm 15.0\%$  of  $B_T$ ) and, in addition, 45% of  $MFS_{Sa}$  and 41% of  $MFS_B$  belonged to the calcified species *Peyssonnelia rosa-marina*. Similar low abundances of members of the order Corallinales (<2%) have been found on other *Peyssonnelia* beds dominated by *P. rosa-marina* or *Peyssonnelia* sp. in the Balearic Islands (Ballesteros, 1994), which has been explained by the burial of corallines in bottoms with a high sedimentation rate, while *Peyssonnelia* and other fleshy species accumulate in ripple mark depressions (Ballesteros, 1994; Bordehore *et al.*, 2003). Values of  $H'$  and  $J'$  in relation to algal surface were similar to values found on *S. fruticulosus* beds, but in relation to biomass, the *P. inamoena* community presented higher values of  $H'_B$  and  $J'_B$  (Fig. 3). *Peyssonnelia* beds seem to be abundant and diverse on the continental shelf of the Balearic Islands. In this regard, besides the *P. inamoena* and *P. rubra* identified here and in a previous work (Joher *et al.*, 2012), some bottoms dominated by different *Peyssonnelia* species have been identified previously in the Balearic Islands (Ballesteros, 1994) as well as in other areas of the Western Mediterranean Sea (Huvé, 1954; Carpine, 1958; Parenzan, 1960; Bourcier, 1968; Augier & Boudouresque, 1978; Basso, 1990). In addition, the *P. inamoena* beds studied here also show a great abundance of other congeneric species (*P. rosa-marina*, *P. harveyana*, *P. rubra*), suggesting that all *Peyssonnelia* beds could constitute a single habitat, where the different species could become dominant as a response to slightly different environmental conditions. However, further studies are required on this issue.



**Fig. 3:** Characteristics of the three studied communities (mean and standard deviation). A) Total algal surface (Sa<sub>T</sub>) and total biomass (B<sub>T</sub>). The percentage of the maerl-forming species is given for both parameters. B) Shannon's diversity (H') and Pielou's evenness (J') both based on algal surface (Sa) and biomass (B). Abbreviations: Spo, *Spongites fruticulosus* beds; Lam, *Laminaria rodriguezii* forests; Pey, *Peyssonnelia inamoena* beds.



**Fig. 4:** Results of the SIMPER test based on algal surface (Sa) and biomass (B) for the three communities. The species summarizing 70% of total contribution to the similarity of the samples are given. Abbreviations: Spo, *Spongites fruticulosus* beds; Lam, *Laminaria rodriguezii* forests; Pey, *Peyssonnelia inamoena* beds.

**Table 2.** Main characteristics of the collected samples/replicates. Abbreviations: Spo, *Spongites fruticulosus* beds; Lam, *Laminaria rodriguezii* forests; Pey, *Peyssonnelia inamoena* beds; MC, Menorca Channel; SM, Southern Menorca; n, number of species; IFO, Index of Floral Originality; Sa<sub>p</sub>, total algal surface; B<sub>p</sub>, total biomass; MSF<sub>Sa</sub> and MSF<sub>B</sub>, maërl-forming species according to total algal surface and biomass; H<sup>Sa</sup> and H<sup>B</sup>, Shannon's diversity based on algal surface and biomass; J<sup>Sa</sup> and J<sup>B</sup>, Pielou's evenness based on algal surface and biomass.

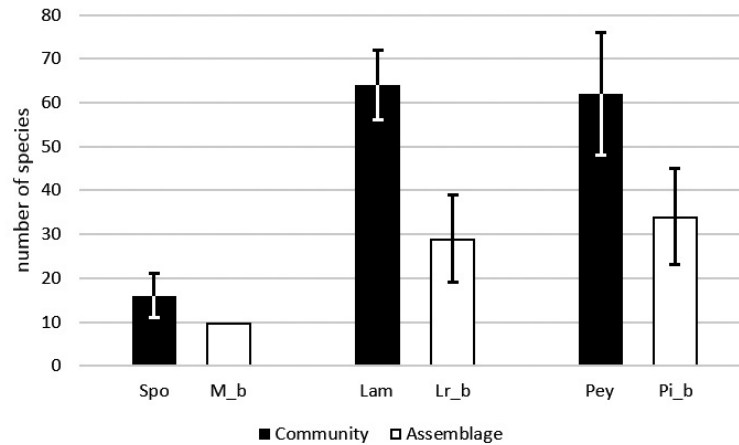
Location	Spo I		Spo II		Spo III		Spo IV		Spo V		Spo VI		Spo VII		Lam I-1		Lam I-2		Lam II-1		Lam II-2		Pey I-1		Pey I-2		Pey II-1		Pey II-2	
	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	MC	SM	SM	SM	SM	SM	SM	SM	SM
Depth (m)	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-50-60	-61	-61	-62	-62	-62	-62	-62	-64	-64	-64	-64	-64	-65	-65	-65	-65
Date of collection	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	13/05/09	15/05/09	15/05/09	15/05/09	15/05/09	15/05/09	15/05/09	15/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09	19/05/09
n	12	14	18	19	26	10	10	15	15	70	70	71	60	60	54	54	54	54	54	54	77	77	67	67	45	45	57	57	57	57
IFO	0.107	0.087	0.139	0.142	0.134	0.142	0.142	0.088	0.088	0.182	0.182	0.178	0.168	0.168	0.159	0.159	0.159	0.159	0.159	0.159	0.230	0.230	0.203	0.203	0.214	0.214	0.194	0.194	0.194	0.194
Sa <sub>p</sub> (cm <sup>2</sup> m <sup>-2</sup> )	6776	8055	269	5242	1451	3248	2718	4426	4065	3577	2545	2886	2311	541	906	906	906	906	906	906	266	266	182	182	38	38	10	10	10	10
MFS <sub>Sa</sub> (cm <sup>2</sup> m <sup>-2</sup> )	5975	7300	100	3350	990	3175	2485	1225	1046	448	448	448	448	448	448	448	448	448	448	448	2.326	2.326	2.534	2.534	2.370	2.370	2.004	2.004	2.004	2.004
H <sup>Sa</sup> (bits)	1.880	1.957	3.564	2.641	2.853	1.380	1.380	2.121	3.989	3.755	3.755	3.755	3.755	3.755	3.755	3.755	3.755	3.755	3.755	3.755	0.371	0.371	0.418	0.418	0.431	0.431	0.344	0.344	0.344	0.344
J <sup>Sa</sup>	0.524	0.514	0.855	0.622	0.607	0.416	0.416	0.543	0.649	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.371	0.371	0.418	0.418	0.431	0.431	0.344	0.344	0.344	0.344
B <sub>T</sub> (g dw m <sup>-2</sup> )	640	758	11	366	101	318	264	148	134	81	60	48	8	11	11	11	11	11	11	11	68	68	48	48	8	8	11	11	11	11
MFS <sub>B</sub> (g dw m <sup>-2</sup> )	598	730	10	335	99	318	249	122	105	58	44	16	3	1	1	1	1	1	1	1	26	26	16	16	3	3	1	1	1	1
H <sup>B</sup> (bits)	1.564	1.677	1.809	1.909	1.583	1.218	1.218	1.916	2.425	2.718	2.718	2.718	2.766	2.766	2.944	2.944	2.944	2.944	2.944	2.944	2.635	2.635	2.594	2.594	3.074	3.074	2.419	2.419	2.419	2.419
J <sup>B</sup>	0.436	0.441	0.434	0.449	0.337	0.367	0.367	0.490	0.396	0.442	0.442	0.442	0.468	0.468	0.512	0.512	0.512	0.512	0.512	0.512	0.421	0.421	0.428	0.428	0.560	0.560	0.415	0.415	0.415	0.415

Although the spatial structure of the communities studied here was different, differences in species composition were small, as reflected in the low values of IFO calculated for each of the studied communities (Fig. 1). In this sense, previous reports of bottoms dominated by the kelp *L. rodriguezii* as 'fonds à prâlines et *Laminaria rodriguezii*' (Molinier, 1956; Gautier & Picard, 1957; Pères & Picard, 1964), together with the high similarities between *S. fruticosus* beds and *L. rodriguezii* forests highlighted in this study, suggest the existence of a gradient moving from the *S. fruticosus* beds to the *L. rodriguezii* forests. Whether this is driven by natural environmental factors or by anthropogenic pressures would require further work. However, in this sense, recent studies pointed out that the abundances of this endemic kelp on detritic bottoms geographically differ depending on commercial trawling pressure, since well-developed *L. rodriguezii* kelps are only found in specific areas of the Menorca channel with low trawling pressure (Joher *et al.*, 2012). Finally, the development of *Peyssonnelia* spp. communities could also be favoured by adverse local environmental conditions for the development of maërl beds. Thus, the natural presence of high sedimentation rates and/or changes induced by trawling, such as turbidity, could enhance the abundance of Peyssonneliaceae over Corallinales, as previously observed in Alicante (Spain) and Malta (Bordehore *et al.*, 2000).

ROV dives have been extremely useful for finding extensive beds of the three targeted communities and, in fact, this is the most advisable method to localize specific communities in deep-water, highly patchy detritic landscapes, rather than using destructive dredges or Scuba-diving. Regarding the sampling method, the number of species reported for each community in this work is significantly higher than the values found in corresponding assemblages sampled by bottom trawling (Fig. 5) (Joher *et al.*, 2012). This was unexpected since the sampled surface was much larger in the collections made by bottom trawling. Bottom trawls have a larger mesh size than beam trawls (20 mm vs 10 mm), which could explain this increase in the *L. rodriguezii* and *P. inamoena* communities, even when sampling much smaller surfaces. In the case of the *S. fruticosus* community, Box-Corer dredges completely prevented any loss of sample and probably this is the reason explaining the increase. Thus, Box-Corer dredges or beam trawls seem to be good sampling methods for studying the composition and structure of deep-water detritic communities, although bottom trawls are equally effective if the main assemblages have to be identified in large areas.

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**Fig. 5:** Comparison of the number of species (mean and standard deviation) of the communities studied here and the corresponding assemblages described in Joher *et al.* (2012). Abbreviations: Spo, *Spongites fruticulosus* beds; M\_b, maërl beds in Joher *et al.* (2012); Lam, *Laminaria rodriguezii* forests; Lr\_b, *Laminaria rodriguezii* beds in Joher *et al.* (2012); Pey, *Peyssonnelia inamoena* beds; Pi\_b, *P. inamoena* beds in Joher *et al.* (2012).

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