Deep-water macroalgal-dominated coastal detritic assemblages on the continental shelf off Mallorca and Menorca (Balearic Islands, Western Mediterranean)

Abstract: We present a quantitative physiognomic characterization of major macroalgal-dominated assemblages on coastal detritic bottoms of the continental shelf off Mallorca and Menorca (Balearic Islands, Western Mediterranean). In late spring of 2007 and 2008, 29 samples were collected by bottom trawling at depths between -52 and -93 m. These samples were then sorted and identified to their lowest taxonomic level. Statistical analyses distinguished six different assemblage types: shallower water environments (-52 to -65 m in depth) were characterized by *Osmundaria volubilis* and *Phyllophora crispa* meadows and two types of *Peyssonnelia* beds; two assemblage types, *Laminaria rodriguezii* beds and maërl beds, were only present in deep-water environments (-77 to -81 m); and an assemblage dominated by *P. crispa* and *Halopteris filicina* was found in both shallow and deep waters (-57 to -93 m). We assess the distribution of these six assemblage types through the studied area.

Keywords: algal assemblages; bottom trawl; detritic bottoms; macroalgae; Mediterranean Sea.

Introduction

Coastal detritic bottoms are characterized by a large amount of particles of organic origin, a low percentage of silt, and, typically, by the absence of muddy particles (Pérès 1985). They constitute a main habitat within the sedimentary bottoms of continental shelves occurring close to shore, usually at more than -25 m in depth (Pérès 1985). Assemblages developing in these coastal detritic bottoms encompass a large range of species and functional diversities and also harbor a vast number of rare and interesting species that are often restricted to these kinds of assemblages (Cabioc 1969, Ballantine et al. 1994, Bellan-Santini et al. 1994, Grall and Glémarec 1997, Foster 2001, Steller et al. 2003). In addition, coastal detritic assemblages act as nursery grounds for various invertebrates and fishes, including commercial species (Massuti et al. 1996, Colloca et al. 2003, Kamenos et al. 2004, Massuti and Reñones 2005), and they shelter many calcareous algae and calcareous invertebrates, which indicates that these assemblages are major carbonate producers (Ballesteros 1994, Canals and Ballesteros 1997).

The Mediterranean Sea has a long tradition in the study of coastal detritic assemblages. Research on the flora began at the end of the 19th century and the beginning of the 20th century (Rodríguez-Femenías 1889, Mazza 1903, de Buen 1905, 1934, Bellón-Uriarte 1921). Later, diverse authors highlighted the high biodiversity and reported different assemblage types such as *Laminaria rodriguezii* beds, maërl beds, and free-living *Peyssonnelia* beds (Pérès and Picard 1963, 1964, Picard 1965, Giaccone 1973, Augier and Boudouresque 1978, Bourcier 1982, Ballesteros et al. 1993). Besides this major literature, other significant studies have focused on maërl (Dieuze 1940, Feldmann 1943, Gautier and Picard 1957, Jacquotte 1961, 1962, Ballesteros 1988, Basso 1995a, B, Bordehore et al. 2003, Piazzi et al. 2003, 2004, Agnesi et al. 2011), *L. rodriguezii* beds (Feldmann 1934, Molinier 1956, 1960), and *Peyssonnelia* beds (Huvé 1954, Carpine 1958, Laborel et al. 1961,
Ballesteros 1994). However, all these different assemblage types have been described separately, and although they have several species in common, no attempts have been made to find out whether they are different and can be distinguished by statistical methods.

Direct sampling (e.g., scuba diving) in the deep waters of the continental shelf, where coastal detritic bottoms develop, has severe limitations due to restricted sampling time, long decompression stops, and diver performance decrease (UNEP-MAP-RAC/SPA 2008). Although scuba diving has been occasionally used to describe species composition on coastal detritic bottoms (Giaccone 1972, Ballesteros 1988, 1994, Piazzi et al. 2003, 2004), indirect sampling methods (e.g., dredging, trawling, or video surveys with remotely operated vehicles) are those usually used (Cailliet et al. 1999, Bax and Williams 2001). Thus, dredges are the most common practice used in the description of algal assemblages (Basso 1995a,b, Bordehore et al. 2003), whereas trawls are probably the most frequently used method in the description of fish and invertebrate assemblages (Bertrand et al. 2002, Massuti and Reñones 2005, Fanelli et al. 2007, García-Muñoz et al. 2008, Ordines and Massuti 2009).

The Balearic Islands have a central position in the western Mediterranean Sea and are the emergent parts of a promontory including four major islands. The Balearic shelf can be divided into two geographic sectors: the Mallorca-Menorca shelf, covering 6418 km², and the smaller Eivissa-Formentera shelf, with a total surface of 2709 km² (Acosta et al. 2002). Coastal detritic bottoms have been largely identified on the Mallorca-Menorca shelf (de Buen 1934, Alonso et al. 1988, Fornós et al. 1988, Canals and Ballesteros 1997, Fornós and Ahr 1997, Massuti and Reñones 2005) and have been characterized in terms of Foraminifera (Milker et al. 2009) and megabenthos (Massuti et al. 1996, Massuti and Reñones 2005, Ordines and Massuti 2009). Seaweeds are a major component of these coastal detritic bottoms, but they have been taken into account in a somewhat cursory manner in descriptive studies that try to cover all benthic groups (e.g., de Buen 1934, Canals and Ballesteros 1997); the only literature providing a full list of seaweeds thriving on these bottoms is the description of Peyssonnelia and maërl beds by Ballesteros (1994).

Hence, in this study we attempted to identify the main assemblage types that can be distinguished on coastal detritic bottoms of the continental shelf off Mallorca and Menorca, according to the abundance of the different algal species. We used bottom trawling as a sampling technique. In addition, we provide geographical and bathymetric distributions of these assemblages.

Materials and methods

The present study was located on the continental shelf off Mallorca and Menorca (Balearic Islands, Western Mediterranean; Figure 1). This shelf is generally narrow, except at the south of Mallorca and in the channels between Mallorca and Menorca and Mallorca and Cabrera, where it becomes larger and has a gentle slope (Acosta et al. 2002). The absence of rivers reduces the presence of terrestrial sediments, and therefore, most of the sediments are usually of biogenic origin (Canals and Ballesteros 1997, Fornós and Ahr 1997) and contain a high percentage of carbonates (Acosta et al. 2002). In addition, light transmittance through the water is very high (Ballesteros and Zabala 1993, Canals and Ballesteros 1997), allowing algal-dominated benthic communities to develop deeper than on other Mediterranean continental coasts (Ballesteros and Zabala 1993).

Samples of coastal detritic assemblages were collected at depths ranging from -52 to -93 m (Figure 1) in the late spring (May/June) of 2007 and 2008 during the MEDITS_ES05 bottom trawl surveys. Samples were collected with experimental GOC73 equipment and followed the general specifications for the MEDITS surveys (Dremière et al. 1999, Fiorentini et al. 1999, Bertrand et al. 2002). A total of 29 samples were collected; each sample consisted on a haul obtained during 30 min at a vessel speed of 3 knots. When the hauls arrived on board, algae were sorted and a 6 l sample was obtained from every haul and preserved in 4% formalin in seawater. Once in the laboratory, samples were washed, sorted, and identified.

To visualize the affinities between samples, we used a nonmetric multidimensional scaling (nMDS) ordination (Kruskal and Wish 1978) based on a Bray-Curtis similarity matrix calculated from $S_{a_{i}}$ data. A hierarchical group average agglomerative clustering method accompanied by the SIMPROF test (Clarke et al. 2008) adjusted to 9999
permutations and a 0.1% significance level according to Potter et al. (2001) was used to explore the potential grouping structures among samples. Finally, the percentage similarity routine (SIMPER) was run to quantify the contribution of each species to the similarity/dissimilarity between the varying SIMPROF groups. All the analyses were performed with PRIMER version 6 software (PRIMER-E Ltd., Plymouth, UK; Clarke and Warwick 2001).

### Results

A total of 6 different assemblages (Table 1) and 132 algal taxa were identified (Table 2). Some of the taxa (Cystoseira sp., Gracilaria sp., Griffithsia sp., Peyssonnelia sp., Polysiphonia sp. 1 and 2, Rhodophyta unidentified 1 and 2, and Sphacelaria sp.) could not be identified to species level because we either had only small pieces of the

### Table 1

| Assemblage type | Minimum depth range (m) | n | Minimum | Maximum | \( S_a_{ih} \) (cm\(^2\) m\(^{-2}\)) | Minimum | Maximum |
|----------------|-------------------------|---|---------|---------|---------------------------------|---------|---------|
| Ov/Pc_m        | -52 to -60              | 47 ± 6 | 41 | 56 | 30,945 ± 15,358 | 11,138 | 51,608 |
| Pi_b           | -62                     | 34 ± 11 | 26 | 42 | 620,000 ± 495,000 | 270 | 970 |
| Pr_b           | -60 to -65              | 55 ± 7 | 49 | 63 | 138,451 ± 31,210 | 110,162 | 171,937 |
| Lr_b           | -77 to -81              | 39 ± 10 | 20 | 40 | 17,926 ± 5005 | 12,649 | 22,605 |
| M_b            | -77                     | 10 | 10 | 10 | 306 | 306 | 306 |
| Pc/Hf_m        | -57 to -93              | 38 ± 9 | 24 | 59 | 3511 ± 1963 | 1194 | 6580 |

Note that M_b is only represented by 1 sample. Assemblage types: Lr_b, Laminaria rodriguezii beds; M_b, maërl beds; Ov/Pc_m, Osmundaria volubilis and Phyllophora crispa meadows; Pc/Hf_m, Phyllophora crispa and Halopteris filicina meadows; Pi_b, Peyssonnelia inamoena beds; Pr_b, Peyssonnelia rubra beds.
| Species                                      | Ov/Pc_m     | Pi_b        | Pr_b          | Lr_b          | M_b          | Pc/HF_m     |
|---------------------------------------------|-------------|-------------|---------------|---------------|--------------|-------------|
| Acrodiscus vidovichii (Meneghini) Zanardini |             |             |               |               |              | 1.01±3.91   |
| Acrosorium ciliatum (Harvey) Kylin          | 3.31±4.74   |             |               |               |              | 2.26±3.17   |
| Acrothamnion preissii (Sonder) E.M. Wollaston | 13.49±19.63 | 36.11±0.08  | 70.45±108.20  |               |              | 57.29±146.10|
| Alsidium corallinum C. Agardh               | 3.45±7.71   |             |               |               |              |             |
| Apoglossum ruscoforium (Turner) J. Agardh   |             |             |               | 1.67±2.89     |              | 0.02±0.10   |
| Asparagopsis taxiformis (Delile) Tresvan de Saint-León | 3.17±0.32 | 0.84±0.01   |               |               |              | 0.50±1.35   |
| Balliella cladoderma (Zanardini) Athanasiasis | 0.31±0.53  |             |               |               |              |             |
| Bometia secundifera (J. Agardh) Thuret      |             |             |               |               |              | 0.02±0.09   |
| Botryocladia chiajeana (Meneghini) Kylin    | 1.33±2.99   |             | 13.50±14.20   |               |              | 0.78±2.65   |
| Botryocladia madagascariensis G. Feldmann   | 677.94±1515.92 | 5597.08±7088.13 | 0.07±0.12     |               |              | 4.64±11.63  |
| Brongniartella byssoids (Goodenough et Woodward) F. Schmitz | 11.12±23.14 |             |               |               |              | 3.00±10.68  |
| Calliblepharis jubata (Goodenough et Woodward) Kützing |             |             | 2.36±0.08     |               |              |             |
| Callophyllis laciniata (Hudson) Kützing     | 22.19±49.61 | 207.66±359.68 |             |               |              | 1.96±5.45   |
| Chamaia parvula (C. Agardh) Harvey          | 0.93±2.08   |             |               |               |              | 0.13±0.41   |
| Chrysymenia ventricosa (J.V. Lamouroux) J. Agardh | 9.43±16.34 |           |               |               |              | 0.01±0.05   |
| Chylocladia verticillata (Lightfoot) Blding | 36.15±56.05 | 5.04±6.60   |               |               |              | 3.42±9.97   |
| Corallina elongata J. Ellis et Solander      |             |             |               |               |              | 0.01±0.03   |
| Cuvania attenuata (C. Agardh) J. Agardh     |             |             |               |               |              | 0.01±0.03   |
| Cryptonemia lamation (Bertoloni) J. Agardh   | 1.55±2.40   | 0.29±0.40   | 2.04±3.53     | 1.17±2.02     |              | 0.19±0.37   |
| Cryptonemia longiarticulata Funk            | 182.62±224.38 | 0.32±0.05   | 44.05±38.19   |               |              | 153.30±401.76|
| Cryptonemia tuniformis (Bertoloni) Zanardini | 88.43±1170.94 | 24.42±18.30 | 4668.64±3667.67 |               |              | 45.98±38.64 |
| Cryptonemia sp.                             | 0.14±0.32   | 0.36±0.63   | 0.04±0.08     |               |              | 0.17±0.50   |
| Cryptopleura ramosa (Hudson) L. Newton      | 1.68±2.58   | 0.63±0.89   | 23.66±8.56    | 3.15±4.82     |              | 1.00±2.17   |
| Dasya baillouiana (S.G. Gmelini) Montagne   | 1.06±2.38   |             |               |               |              |             |
| Dasya rigescens Zanardini                   |             |             |               |               |              | 0.03±0.12   |
| Erythroglossum balearicum J. Agardh ex Kylin |             |             |               |               |              | 0.01±0.03   |
| Ethelia vanbosseae Feldmann                 |             |             |               |               |              | 0.03±0.12   |
| Eupogonion planus (C. Agardh) Kützing       | 23.15±34.14 |             | 19.95±2.73    |               |              | 0.18±0.40   |
| Eupogonion spinulatus (C. Agardh) Kützing   | 8.33±13.70  |             |               |               |              | 0.89±3.13   |
| Gloioclada furcata (C. Agardh) J. Agardh    | 6.16±10.06  |             | 86.78±78.32   | 0.17±0.29     |              | 0.60±2.14   |
| Gloioclada microspora (Bomet et Bomet et Rodríguez y Femenías) N. Sánchez et C. Rodríguez-Prieto et Berezívar | 39.27±50.90 | 646.67±534.78 | 10.37±5.29 | 2.42±14.55 | 20.34±15.34 |
| Gracilariopsis venosa E.M. Wollaston        |             |             |               |               |              |             |
| Gracilaria repens (C. Agardh) Sánchez et Rodríguez-Prieto | 25.03±55.96 | 34.96±60.55 | 14.20±19.41 | 0.62±1.31   |
| Gracilaria bursa-pastoris (S.G. Gmelini) P.C. Silva | 64.12±90.68 | 1.93±2.72 | 2.13±3.70 | 1.62±5.20 |
| Gracilaria corallina Zanardini              | 5.12±5.12   | 3.65±0.35   | 1936.06±2633.57 | 2.62±3.70      |              | 49.43±151.74|
| Gracilaria sp.                              | 17.02±28.06 | 0.68±0.06   | 3.16±5.47     |               |              | 1.34±3.45   |
| Griffithsia sp.                             |             |             |               |               |              | 0.01±0.02   |
| Haliptilon virgatum (Zanardini) Garby et H.W. Johansen |             |             |               |               |              | 0.16±0.63   |
| Halopithys incurvus (Hudson) Batters        | 742.69±832.77 | 14.19±16.55 | 48.18±65.19 | 21.16±32.50 | 1.60±5.45   |
| Species                        | Ov/Pc_m | Pi_b  | Pr_b  | Lr_b  | M_b  | Pc/HF_m |
|-------------------------------|---------|-------|-------|-------|------|---------|
| Halymenia latifolia (P.L. Crouan et H.M. Crouan ex Kützing) | 0.75±1.68 | 4.90±8.48 | 2.70±4.68 | 2.65±5.13 |
| Halymeniaceae unidentified 1  | 176.33±167.76 | 7.87±2.26 | 720.53±903.28 | 61.65±42.33 | 0.35  | 103.11±168.52 |
| Halymeniaceae unidentified 2  | 0.13±0.29 |
| Haraldia lenormandii (Derbes & Solier) Feldmann | 5.4±11.86 | 0.08±0.14 | 0.33±1.26 |
| Hypnea spinella (C. Agardh) Kützing | 2.99±4.23 | 0.05±0.08 | 0.02±0.08 |
| Hypoglosum hypoglossoides (Stackhouse) F.S. Collins & Hervey | 1.33±1.89 | 2.82±4.88 | 0.05±0.21 |
| Irvinea boergesenii (Feldmann) R.J. Wilkes, L.M. McIvor & Guiry | 3.04±3.59 | 122.06±211.41 | 0.15±0.76 |
| Kallymenia patens (J. Agardh) Codomier ex P.G. Parkinson | 9.90±8.91 | 80.17±114.02 | 19.07±36.35 |
| Kallymenia requienii (J. Agardh) J. Agardh | 80.14±95.60 | 447.25±774.65 | 8.01±21.62 |
| Laurencia chondrioides Bøgesen | 25.99±34.51 | 1.08±2.70 |
| Leptofauchea coralligena Rodríguez-Prieto & O. De Clerck | 4.57±28.39 | 30.80±140.77 | 7.24±9.22 |
| Lithothamnion corallioides (P.L. Crouan et H.M. Crouan) | 317.31±328.64 | 10.26±13.92 | 19.9±23.86 |
| P.L. Crouan et H.M. Crouan | 197.44±308.70 | 1.75±1.70 | 4.59±40.08 | 61.17±83.92 |
| Lomentaria subdichotoma Ercegovíc | 0.29±0.66 | 2.35±4.06 | 0.080±0.22 |
| Lomentaria sp. | 0.04±0.06 | 0.11±0.06 | 0.44±0.10 |
| Lophocladia lallemandii (Montagne) F. Schmitz | 3.24±7.25 | 75.84±74.06 | 0.44±0.10 |
| Meredithia microphylla (L. Agardh) J. Agardh | 7.58±10.71 | 0.07±0.09 | 139.48±130.12 | 5.26±7.11 |
| Mesophyllum expansum (Philippi) Cabioch et Mendoza | 23.79±32.59 | 10.97±10.55 |
| Myriogramme minuta Kylin | 34.79±60.74 | 0.64±2.47 |
| Myriogramme tristomatica (J.J. Rodríguez ex Mazza) | 0.11±0.01 | 0.01±0.02 |
| Boudouresque | 0.14±31.35 | 0.20±0.60 |
| Nemastoma dumontioides J. Agardh | 10.884.44±6836.62 | 1.77±1.54 |
| Neurocaulon foliosum (Meneghini) Zanardini | 5.69±1.49 | 16.02±9.65 | 291.04±343.42 |
| Nitophyllum flabellatum Ercegovíc | 14.02±31.35 | 0.42±0.72 | 11.24±28.76 |
| Nitophyllum punctatum (Stackhouse) Greville | 0.23±0.51 | 0.29±0.51 |
| Osmundaria valubilis (Linnaeus) R.E. Norris | 399.24±680.74 | 0.01±0.01 |
| Osmundea pelagicae (Schiffn.) K.W. Nam | 23.79±32.59 | 10.97±10.55 |
| Peyssonnelia magnifica Ercegovíc | 347.99±602.74 |
| Peyssonnelia armoricana (P.L. Crouan et H.M. Crouan) | 0.64±2.47 |
| Weber-van Bosse | 0.71±1.59 | 2440.80±4135.88 | 1.18±3.34 |
| Peyssonnelia bomenii Boudouresque et Desinot | 79.80±138.22 | 0.86±3.24 |
| Peyssonnelia dubyi P.L. Crouan et H.M. Crouan | 1.28±2.86 | 4.96±8.59 | 3.59±11.36 |
| Peyssonnelia harveyana P.L. Crouan et H.M. Crouan ex J. Agardh | 317.21±401.10 | 19.001.68±17.403.53 | 23.73±25.08 |
| Peyssonnelia inamoena Pilger | 27.76±12.88 | 2.21±3.13 | 5.23±13.54 |
| Peyssonnelia rosa-marina Boudouresque et Desinot | 255.27±2975.42 |
| Peyssonnelia rubra (Greville) J. Agardh | 14.76±16.72 | 14.62 | 2.23±3.98 |
| Peyssonnelia squamaria (S.G. Melini) Decaisne | 18.39±16.29 | 0.94±1.63 | 0.02±0.07 |
| Species                        | Ov/Pc_m | Pl_b  | Pr_b  | Lr_b  | M_b  | Pc/HF_m |
|-------------------------------|---------|-------|-------|-------|------|---------|
| Peyssonnelia sp.              | 9.06±12.81 | 1191.59±1878.57 | 0.18±0.38 |
| Phyllophora crispum (Hudson) P.S. Dixon | 7563.80±4533.60 | 36,432.34±1784.54 | 386.73±110.43 | 0.72 | 936.69±938.63 |
| Phyllophora heredia (Clemente) J. Agardh | 38.41±28.84 | 2106.79±1081.54 | 100.45±170.53 | 5.85±12.40 |
| Phymatolithon calcareum (Pallas) W.H. Adey et D.L. McKibbin | 260.59±311.72 | 29.98±19.31 | 6.82±7.45 | 6.56±9.44 |
| Plocamiumcartilagineum (Linnaeus) P.S. Dixon | 0.06±0.08 | 7.92±7.87 | 1.27±1.64 | 0.45±0.77 |
| Polysiphonia elongata (Hudson) Sprengel | 304.56±430.81 | 45.44±46.42 | 17.69±57.89 |
| Polysiphonia omata J. Agardh | 0.06±0.18 |
| Polysiphonia perforans Cormaci, G. Furnari, Pizzuto et Serio | 4.95±7.65 | 0.01±0.01 |
| Polysiphonia subulifera (C. Agardh) Harvey | 841.80±1523.19 | 10.21±14.44 | 0.80±1.38 | 22.88±60.16 |
| Polysiphonia sp. 1 | 358.07±1067.31 | 0.07±0.09 | 130.22±222.25 | 23.49±81.76 |
| Polysiphonia sp. 2 | 0.92±2.06 |
| Pterothamnion crispum (Ducluzeau) Nägeli | 0.39±1.29 |
| Pterothamnion plumula (J. Ellis) Nägeli | 0.06±0.16 |
| Radicilingua reptans (Kylin) Papenfuss | 0.01±0.02 |
| Rhodophyta unidentified 1 | 0.09±0.21 | 15.65±13.39 | 0.39±0.68 |
| Rhodophyta unidentified 2 | 14.97±22.63 | 1.53±1.65 | 176.78±253.94 | 7.93±13.33 | 9.78±15.80 |
| Rhodymenia sp. | 83.25±149.50 | 5.80±8.20 | 1158.36±147.10 | 1.04±1.80 | 10.77±13.20 |
| Rodriguezella pinnata (Kützing) F. Schmitz ex Falkenberg | 21.07±47.31 | 72.58±117.34 | 0.07±0.28 |
| Rodriguezella strafforelli F. Schmitz ex J.J. Rodríguez y Femenías | 33.96±70.56 | 90.62±52.02 | 0.08±0.31 |
| Rosiphlaea tinctoria (Clemente) C. Agardh | 916.19±995.63 | 0.07±0.10 | 1199.27±1958.53 | 21.88±45.83 |
| Sebdenia dichotoma Berthold | 11.55±19.14 | 0.29±1.12 |
| Sebdenia monardiana (Montagne) Berthold | 0.34±1.30 |
| Sebdenia rodrigueziana (Feldmann) Codomier ex Parkinson | 26.84±46.69 |
| Sphaerococcus coronopifolius Stackhouse | 99.05±127.57 | 0.21±0.30 | 3685.12±3294.16 | 0.25±0.43 | 11.69±25.53 |
| Sphaerococcus rhizophylloides J.J. Rodríguez y Femenías | 75.58±166.86 | 579.73±478.23 | 11.36±31.89 |
| Sphondylanthanion multifidum (Hudson) Nägeli | 0.22±0.48 |
| Spongites fruticulosa Kützing | 784.16±1040.53 | 34.34±38.71 | 508.81±385.12 | 241.69±101.88 | 190.91 | 166.72±220.93 |
| Wrangelia penicillata (C. Agardh) C. Agardh | 0.11±0.42 |
| Chlorophyta | |
| Caulerparacerosoma var. cyndracea (Sonnerat) Verlaque, Huismann et Boudoureque* | 1.14±3.22 |
| Codium bursa (Oliv) C. Agardh | 90.27±168.62 | 17.91±17.24 | 4827.05±7427.34 | 27.1±51.43 |
| Flabellia petiolata (Turra) Nizamuddin | 101.91±53.58 | 11.53±11.07 | 1000.52±820.63 | 144.78±168.93 | 19.03 | 183.55±325.93 |
| Halimeda tuna (J. Ellis et Solander) J.V. Lamouroux | 0.54±1.20 | 94.80±164.19 | 8.61±14.92 | 0.80±2.23 |
| Micractynium tenuiss J.E. Gray | 5.60±10.65 | 1.78±3.09 |
| Palmarhysthymum crassum (Naccari) Rabenhorst | 6.03±12.00 | 79.18±68.97 | 0.97±2.42 |
| Umbraulva aouascens (P.I. Dangeard) G. Fumari | 7.76±17.36 | 1.27±1.79 | 95.36±88.24 | 0.54±0.94 | 8.22±21.71 |
| Valonia macrophysa Kützing | 1.68±2.43 | 4.63±4.91 | 135.84±87.38 | 0.67±1.66 |
| Ochrophyta-Paeophyceae | |
| Aglaophenia chilosa Falkenberg stage | 5.65±5.37 | 0.15±0.21 | 0.17±0.37 |
| Arthrocladia villosa (Hudson) Duby | 0.21±0.30 |
| Species                        | Lr_b | M_b | Pc/Hf_m |
|-------------------------------|------|-----|----------|
| Asperococcus bullosus         | 0.25 | 0.66|          |
| Carpomitra costata           | 0.02 | 0.07|          |
| Cladostephus spongiosus      | 0.48 | 0.67|          |
| Cutleria chilosa             |      |     | 4.26     |
| Cystoseira spinosa var. compressa | 196.80 | 69.15 | 119.99 |
| G. Fumari, G. Giaccone, B. Scammarca et D. Serio | | | 3.47 |
| Cystoseira zosteroides       | 129.75 | 30.22 | 30.22 |
| Cystoseira sp.               | 0.23 | 0.51|          |
| Dictyopteris lucida          | 12.50 | 143.73 | 143.73 |
| Dictyopteris polypondioides  |      |     |          |
| Dictyota dichotoma           | 372.74 | 8.56 | 31.54 |
| Halopteris filicina          | 1615.52 | 66.78 | 698.93 |
| Hincksia sandriana           |      |     | 0.05 |
| Laminaria rodriguezii        | 800.81 | 1.03 | 2346.45 |
| Sphacelaria sp.              |      |     | 263.80 |
| Sporochnus pedunculatus      | 0.42 | 0.59|          |
| Zanardinia typus             | 181.78 | 3.37 | 5.24 |
| Zonaria tournefortii         | 79.37 | 0.70 | 11.97 |

Table 2 Algal surface area per haul (Sa_H, in cm² m⁻²) for species in each assemblage type. Means and standard errors are given except for M_b (single value) because there was only 1 sample. Invasive species. Assemblage types: Lr_b, Laminaria rodriguezii beds; M_b, maerl beds; Ov/Pc_m, Osmundaria volubilis and Phyllophora crispa meadows; Pc/Hf_m, Phyllophora crispa and Halopteris filicina meadows; Pl_b, Peyssonnelia inamoena beds; Pr_b, Peyssonnelia rubra beds.
specimens or because the specimens were sterile. Some other taxa (Halymeniaceae unidentified 1, *Kallymenia* sp., and *Rhodymenia* sp.) are probably undescribed species. Red algae (Rhodophyta) were the best represented group, with 105 taxa (79.5% of the total taxa), followed by brown algae (Phaeophyceae; 19 taxa, 14.4%), and then green algae (Chlorophyta; 8 taxa, 6.1%). The most abundant species, accounting for 70% of the total algal surface area, were *Phyllophora crispa* (24.0%), *Osmundaria volubilis* (14.8%), *Laminaria rodriguezii* (9.4%), *Peyssonnelia rubra* (9.3%), *Peyssonnelia inamoena* (8.7%), *Halopteris filicina* (3.0%), and the introduced invasive species *Botryocladia madagascariensis* (3.0%). The number of species per haul ranged from 10 to 63, and the total algal surface per haul ($S_{TH}$) ranged from 270 to 171,931 cm$^2$ m$^{-2}$.

Five introduced species, the red algae *Acrothamnion preissii* (found at 10 localities), *Asparagopsis taxiformis* (2 localities), *B. madagascariensis* (11 localities), and *Lophocladia lallemandii* (2 localities), and the green alga *Caulerpa racemosa* var. *cylindracea* (2 localities), were collected (Table 2).

The nMDS plot based on species abundances shows patterns of resemblance among the species composition of different trawls (nMDS stress 0.1; Figure 2). According to the SIMPROF test, the samples may be classified into six different groups assigned to six different assemblages. They are *O. volubilis* and *P. crispa* meadows (*Ov/Pc_m*), two different kinds of *Peyssonnelia* beds, one dominated by *Peyssonnelia inamoena* (*Pi_b*) and another by *P. rubra* (**Pr_b**), *L. rodriguezii* beds (**Lr_b**), maërl beds (**M_b**), and *P. crispa* and *H. filicina* meadows (**Pc/Hf_m**) (Table 1). Looking at the species composition in the six assemblages, some of them had exclusive species, whereas some other species were found throughout the continental shelf off Mallorca and Menorca: *Flabellia petiolata*, Halymeniaceae unidentified 1, *Lithothamnion valens*, *Peyssonnelia rubra*, *Peyssonnelia squamaria*, *P. crispa*, and *Spongites fruticulosa*. This list of common species increased up to 20 when we considered those present in all the assemblages other than maërl beds where erect species were scarce. The assemblage with the maximum number of exclusive species was **Pc/Hf_m**, with 24 exclusive species, followed by **Ov/Pc_m** with 7 exclusive species, **Pr_b** with 5 exclusive species, and **Pi_b** with 3 exclusive species. The remaining assemblages did not have any exclusive species (Table 2).

The assemblages **Ov/Pc_m**, **Pi_b**, and **Pr_b** were located in shallow waters (-52 to -65 m) and characterized by a great abundance of *O. volubilis*, *P. crispa*, and *Peyssonnelia* spp., whereas they differed from each other not only in the relative abundance of these species but also in the abundances

![Figure 2](attachment:image.png)

**Figure 2** nMDS ordination with standardized $S_{TH}$ (cm$^2$ m$^{-2}$). Samples are displayed indicating their code, depths range, and corresponding assemblage type. Code shows the year of sampling (7, 2007; 8, 2008) followed by the number of the sample. Assemblage types: **Lr_b**, *Laminaria rodriguezii* beds; **M_b**, maërl beds; **Ov/Pc_m**, *Osmundaria volubilis* and *Phyllophora crispa* meadows; **Pc/Hf_m**, *Phyllophora crispa* and *Halopteris filicina* meadows; **Pi_b**, *Peyssonnelia inamoena* beds; **Pr_b**, *Peyssonnelia rubra* beds.
of accompanying species. Hence, Ov/Pc_m was formed by 5 samples located at depths between -52 and -60 m, in which both O. volubilis and P. crispa were identified as the main species according to the SIMPER test. These meadows were characterized by a high number of species (47±16 per haul) and an Sa_th of 3511±963 cm^2 m^-2 per haul. Pi_b and Pr_b were both Peyssonnelia beds, but they had very different species composition and Sa_th values. Thus, Pi_b, formed by only 2 samples located at -62 m depth, was characterized by the species Peyssonnelia inamoena, A. preissii, and Peyssonnelia rosa-marina, and had a low number of species (34±11) but a high Sa_th (620,000±495,000 cm^2 m^-2). In contrast, the 3 samples of Pr_b, located between -60 and -65 m, were characterized by P. crispa, O. volubilis, and Peyssonnelia rubra and had a greater number of species (mean = 55±7) and lower Sa_th (138,451±31,210 cm^2 m^-2) than Pi_b.

In deeper waters (from -77 to -81 m), two groups were identified, M_b and Lb_b. The M_b included only 1 sample dominated by the corallines Spongnites fruticosula and Lit. valens and had a very low number of species (10) and Sa_th (306 cm^2 m^-2) in comparison with the rest of the samples. In contrast, Lb_b, comprising 3 samples, was dominated by L. rodriguezii and had a higher number of species (29±10) and Sa_th (17.92±5.005 cm^2 m^-2).

Finally, Pc/Hf_m included 15 samples collected in a large range of depths (from -57 to -93 m). Phyllophora crispa, H. filicina, O. volubilis, and Spongnites fruticosula were the most abundant species in this group, with 38±9 species and an Sa_th of 3511±1963 cm^2 m^-2.

**Discussion and conclusions**

Six different coastal detritic bottom assemblages were distinguished on the continental shelf off Mallorca and Menorca based on haul sampling. In general, depth was an important correlate of the distribution of the different assemblages, with the exception of Pc/Hf_m, which occurred in a wide range of depths. Moreover, the limit that separated the relatively shallow from the deep assemblages was situated at around -70 m in depth. Although the decrease in light availability may certainly play an important role in the segregation of these assemblages (Ballesteros and Zabala 1993), we argue here that hydrographic characteristics at the different depths might also contribute to this segregation. The deep waters (from -70 to -200 m) on the Balearic shelf have characteristics of the Intermediate Western Mediterranean Waters whose temperatures are always between 12.5°C and 13°C and have salinities at around 38.15. This is in contrast with shallower waters, which are influenced by both the North Atlantic Surface Waters and the Gulf of Lion Cold Waters and have salinities usually <38 and seasonal temperatures ranging from 14°C to 27°C (Salat and Font 1985, Vives and López-Jurado 1988). The minimal oscillation of temperature in the deeper waters may allow the development of stenothermal species whose growth would be limited in the shallow waters.

The Osmundaria volubilis and Phyllophora crispa meadows (Ov/Pc_m) were found off southeastern Mallorca and western Menorca and were closely related to the assemblage of O. volubilis from the coastal detritic bottoms described previously by Péres and Picard (1963) at Port-Cros (France). However, these authors reported that O. volubilis is usually associated with Rythposula tinctoria rather than P. crispa. Even though O. volubilis is very common in these and other coastal detritic assemblages, it is not a species that can be considered as exclusively associated to these kinds of assemblages, as it is also very abundant on some types of coralligenous outcrops (Ballesteros 1992b) and on infralittoral rocky bottoms (Boudouresque 1973, Augier and Boudouresque 1975, 1978, Serio and Pizzuto 1990, 1992, Ballesteros et al. 1993).

Detritic coastal bottoms dominated by different species of Peyssonnelia have been previously reported on several Mediterranean coasts (see Ballesteros 1994 for a review). Péres and Picard (1963, 1964) reported Peyssonnelia beds in Port-Cros (France) that were dominated by Peyssonnelia rosa-marina f. saxicola together with a smaller quantity of Peyssonella harveyana. Later, Augier and Boudouresque (1978) reported coastal detritic assemblages dominated by Peyssonnelia rosa-marina f. rosa-marina and Peyssonella rubra. Off the Balearic Islands, Peyssonella beds have been reported by de Buen (1905) off the northeastern coast of Menorca, Cape Formentor (Mallorca), and Cabrera at depths between -60 and -160 m and by Ballesteros (1994) off southern Menorca and in the Cabrera Channel at depths between -40 and -90 m. Additionally, this author (loc. cit.) distinguished two types of Peyssonella beds, one dominated by Peyssonella rosa-marina at depths between -48 and -54 m and another by an unidentified Peyssonella located at depths between -40 and -79 m. In the present work, we found a Peyssonella bed (Pi_b) situated at -62 m deep near Dragonera (southwestern Mallorca), where Peyssonella inamoena and Peyssonella rosa-marina were the most abundant species of Peyssonella, and other beds (Pr_b) situated at depths between -60 and -65 m (southern coasts of Mallorca and Menorca) where Peyssonella rubra was the most abundant species of the genus.
Kelp beds dominated by the endemic brown alga *Laminaria rodriguezii* had a low number of species per sample probably because the dense canopy of this kelp prevents the growth of other algae. In fact, Picard (1965) already highlighted that these kelp beds are an impoverished facies on coastal detritic bottoms. Other species that can occasionally be found in these kelp beds are *Cystoseira spinosa* var. *compressa* and *Cystoseira zosteroides*. These two species and *Phyllophorus brevipes* are usually considered to be common in *L. rodriguezii* beds (Giaccone 1967, UNEP/UICN/GIS Posidonia 1990). The low abundance of these accompanying species in our samples may be related to the frequent trawling in the area sampled. In fact, recent collections (2011) from better preserved detritic bottoms in Mallorca and Menorca showed that *C. spinosa* var. *compressa* and *C. zosteroides* can be also extremely abundant in the *L. rodriguezii* beds off the Balearic Islands (C. Rodríguez-Prieto and S. Joher personal observations). The development of LR_b seems to be restricted to particular places, such as the Menorca Channel. Hence, its growth is probably determined by the presence of a detritic bottom composed of rhodoliths, dim light conditions, low and constant water temperature (about 14°C), and unidirectional and constant currents (Molnier 1960, Pérès and Picard 1964, Giaccone 1967, 1971). In fact, the lower limit of *L. rodriguezii* distribution seems to depend on light availability, whereas the upper limit probably depends on temperature (UNEP/UICN/GIS Posidonia 1990).

The maërl bed (M_b) sampled in this study on the eastern coast of Menorca was mainly characterized by a great abundance of *Spongites fruticulosa* and *Lithothamnion valens*. However, this assemblage did not have the usual diversity found on these kinds of detritic bottoms off the Balearic Islands, which may also be dominated by other species such as *Lit. coralliioides* and *Phymatolithon calcareum* or even *Lithophyllum racemus* (de Buen 1905, 1934, Ballesteros et al. 1993, Ballesteros 1994, E. Ballesteros personal observations). In contrast to other maërl beds from the southwestern Mediterranean (Bordelore et al. 2003, Piazzii et al. 2003, 2004), the M_b found in our study was very poor in erect algae. The development of maërl beds in the Mediterranean seems to depend on the existence of high to moderate unidirectional water currents (Picard 1965), and most of them correspond to the facies of *Spongites fruticulosa* described by Pérès and Picard (1964).

The eurybathic meadow (Pc/Hf_m) mainly differed from the other assemblages by a lower abundance of *O. volubilis*. Due to the fact that this meadow does not seem to correspond to any other known assemblage, we cannot rule out the possibility that it corresponds to a methodological artifact due to a mixed sampling in relatively small and patchy heterogeneous areas. Moreover, this bottom may correspond to an algal drift accumulation zone.

Among the five introduced species found in the area, *Botryocladia madagascariensis* and *Acrothamnion preissii* were the most widely distributed, whereas *Caulerpa racemosa* var. *cylindracea*, *Asparagopsis taxifomis*, and *Lophocladia lallemandii* were found only occasionally and they were never abundant. Only *Caulerpa racemosa* var. *cylindracea* has been reported to behave as an invasive alien in coastal detritic assemblages of the northwestern Mediterranean (Klein and Verlaque 2009).

In summary, using algal composition and abundances in the samples collected, bottom trawling proved to be a useful method to characterize and describe assemblages of the continental shelf off Mallorca and Menorca. However, doubts arose for some trawls (e.g., those identified as the eurybathic Pc/Hf_m) because we did not know whether sampling had been performed on highly heterogenous bottoms or if the unique trawl content may represent a mixture of two or more different assemblages. These doubts could also arise when identifying the assemblages according to faunal composition. Dredging, a more frequently used method in the characterization of these algal assemblages, is probably not as useful in describing species groupings, as it does not take into account high spatial heterogeneity. In fact, most of the assemblages found in this study had already been described by other authors using different methodologies (e.g., Pérès and Picard 1964, Ballesteros et al. 1993, Ballesteros 1994), thus confirming that characterization based on algal composition and abundance determined by bottom trawls is a feasible approach for studying deep-water assemblages.

**Acknowledgements:** We acknowledge the Spanish Institute of Oceanography (IEO) for the organization and provision of all facilities needed for the sampling surveys. We also thank the crew of the R/V *Cornide de Saavedra* and the participants who took part in the MEDITS_ES05 surveys for their help and support during the sampling missions. We would like to thank Marc Verlaque, Giovanni Furnari, and Julio Afonso Carrillo for taxonomic help and Natalia Comalada and Núria Orra for helping in laboratory tasks. Sampling surveys were supported by the EVADEMED and INDEMARES projects financed by the IEO and the European Union. Emma Cebrian’s research was funded by the Juan de la Cierva program (MICINN-JDC).
References

Acosta, J., M. Canals, J. López-Martínez, A. Muñoz, P. Herranz, R. Urgelles, C. Palomo and J.L. Casamor. 2002. The Balearic promontory geomorphology (Western Mediterranean): Morphostructure and active processes. Geomorphology 49: 177–204.

Agnesi, S., L. Babbini, G. Bressan, M.L. Cassese, G. Mo and L. Tunesi. 2011. Distribution of märl facies and rhodolith associations in the Italian seas: Current state of knowledge. Proceeding of 42nd Congress of the Italian Marine Biology Society, Olbia, 23–28 May 2011. pp. 43–44.

Alonso, B., J. Guillén, M. Canals, J. Serra, J. Acosta, P. Herranz, J.L. Sanz, A. Calafat and E. Catafau. 1988. Los sedimentos de la plataforma continental balear. Acta Geol. Hisp. 23: 185–196.

Augier, H. and C.F. Boudouresque. 1975. Dix ans de recherches dans la zone marine du Parc National de Port-Cros (France). Troisième partie. Bull. Soc. Sci. Nat. Arch. Toulon Var. 27: 133–170.

Augier, H. and C.F. Boudouresque. 1978. Végétation marine de l'Ile de Port-Cros (Parc National) XVI: Contribution à l'étude de l'épiflore du détritique côtier. Trav. Sci. Parc Natl. Port-Cros 4: 101–125.

Ballantine, D.L., N.E. Aponte and J.G. Holmquist. 1994. Multi-variables statistical analysis of unusual benthic assemblage. Aquat. Bot. 48: 167–174.

Ballesteros, E. 1988. Composición y estructura de los fondos de la plataforma continental balear. Acta Geol. Hisp. 23: 161–182.

Ballesteros, E. 1992b. Els fons rocosos profunds amb Peu. Arx. Secc. Cièn., 101, Institut d'Estudis Catalans, Barcelona. pp. 616.

Ballesteros, E. 1992b. Els fons rocosos profunds amb Osmundaria volubilis (Lin né) R.E. Norris a les Balears. Boll. Soc. Hist. Nat. Balears 35: 33–50.

Ballesteros, E. 1994. The deep-water Peyssonnelia beds from the Balearic Islands (Western Mediterranean). Mar. Ecol. 15: 233–253.

Ballesteros, E. and M. Zabala. 1993. El bentos: El marc físic. In: (J.A. Alcover, E. Ballesteros, and J.J. Fornós, eds.) Història natural de l'arxipèlag de Cabrera. Edit. Moll. Monogr. Soc. Hist. Nat. Balears 2: 663–685.

Ballesteros, E., M. Zabala, J.M. Uriz, A. García-Rubiéx and X. Turón. 1993. El bentos: Les comunitats. In: (J.A. Alcover, E. Ballesteros, and J.J. Fornós, eds.) Història natural de l'arxipèlag de Cabrera. Edit. Moll. Monogr. Soc. Hist. Nat. Balears 2: 687–730.

Basso, D. 1995a. Study of living calcareous algae by a paleontological approach: The non-geniculate Corallinaceae (Rhodophyta) of the soft bottoms of the Tyrrenhian Sea (western Mediterranean). The genera Phymatholithon, Mesophyllum, and Mesophyllum Lemoine. Riv. Ital. Paleontol. S. 100: 575–596.

Basso, D. 1995b. Living calcareous algae by a paleontological approach: The genus Lithothamnion Heydrich nom. cons. from the soft bottoms of the Tyrrenhian Sea (Mediterranean). Riv. Ital. Paleontol. S. 101: 349–366.

Bax, N.J. and A. Williams. 2001. Seabed habitat on the southeastern Australian continental shelf: Context, vulnerability and monitoring. Mar. Freshw. Res. 52: 491–512.

Bellan-Santi, D., J.C. Lacaze and C. Poizat. 1994. Les biocénoses marines et littorales de Méditerranée: Synthèse, menaces et perspectives. Secrétariat de la Faune et de la Flore, Muséum National d'Histoire Naturelle, Paris. pp. 246.

Bellón-Uria, L. 1921. Contribución al estudio de la flora algológica del Mediterráneo Español. Bol. Pesc. 56–58: 81–119.

Bertrand, J.A., L. Gil de Sola, C. Papaconstantinou, G. Relini and A. Souplet. 2002. The general specifications of the MEDITS survey. Sci. Mar. 66 (Suppl. 2): 9–17.

Bordehore, C., A.A. Ramos-Enplá and R. Riosmena-Rodríguez. 2003. Comparative study of two märl beds with different otter trawling history, southeast Iberian Peninsula. Aquat. Conserv: Mar. Freshw. Ecosyst. 13: 43–54.

Boudouresque, C.F. 1973. Recherches de biomiose analytique, structurale et expérimentale sur les peuplements benthiques sciaphiles de Méditerranée occidentale (Fraction algale). Les peuplements sciaphiles de mode relativement calme sur substrats durs. Bull. Mus. Hist. Nat. Marseille 33: 147–225.

Bourrier, M. 1982. Nouvelles localisations et délimitation fine de quelques facies de la biocoenose des fonds détritiques côtiers dans les Parc National sous-marin de Port-Cros (France, Méditerranée). Trav. Sci. Parc Natl. Port-Cros 8: 19–24.

Cabioch, J. 1969. Les fonds de märl de la baie de Morlaix et leur peuplement végétal. Cah. Biol. Mar. 10: 139–161.

Caillet, G.M., A.H. Andrews, W.W. Wakefield, G. Moreno and K.L. Rhodes. 1999. Fish faunal and habitat analyses using trawls, camera sleds and submersibles in benthic deep-sea habitats off Central California. Oceanol. Acta 22: 579–592.

Canals, M. and E. Ballesteros. 1997. Production of carbonate particles by phyto benthic communities in the Mallorca-Menorca shelf, northwestern Mediterranean Sea. Deep-Sea Res. II 46: 611–629.

Carpine, C. 1958. Recherches sur les fonds à Peyssonnelia polymorpha (Zan.) Schmitz de la région de Marseille. Bull. Inst. Océanogr. Monaco 1125: 1–50.

Clarke, K.R. and R.M. Warwick. 2001. Change in marine communities: An approach to statistical analysis and interpretation. 2nd edition. Plymouth Marine Laboratory, UK. pp. 172.

Clarke, K.R., P.J. Somerfield and R.N. Gorley. 2008. Testing of null hypotheses in exploratory community analyses: Similarity profiles and biota-environment linkage. J. Exp. Mar. Biol. Ecol. 366: 56–69.

Colloca, F., M. Cardinale, A. Belluscio and G. Ardizzone. 2003. Pattern of distribution and diversity of demersal assemblages in the Central Mediterranean sea. Estuar. Coast. Shelf Sci. 56: 469–480.

de Buen, O. 1905. La région méditerranéenne des Baléares. Bull. Soc. Zool. Fr. 30: 98–106.

de Buen, O. 1934. Primera campaña biológica a bordo del Xauen en aguas de Mallorca. Trab. Inst. Esp. Oceanogr. 6–11: 7–89.

Dieuzede, R. 1940. Étude d'un fond de pêche d'Algérie: La "gravelle de Castiglione". Bull. Trav. Sta. Aquic. Pesc. 56: 33–57.

Dremière, P.Y., L. Fiorentini, G. Cosimi, L. Leonori, A. Sala and A. Spagnolo. 1999. Escapement from the main body of the bottom
trawl used for the Mediterranean international trawl survey (MEDITS). *Aquat. Living Resour.* 12: 207–217.

Fanelli, E., F. Colloca and G. Ardizzone. 2007. Decapod crustacean assemblages off the west coast of Central Italy. *Sci. Mar.* 71: 19–28.

Feldmann, J. 1934. Les Laminariaceae de la Méditerranée et leur répartition géographique. *Bull. Trav. Sta. Aquic. Pêche Castiglione, Algérie* 2: 143–184.

Feldmann, J. 1943. Contribution à l'étude de la flore marine de profondeur sur les côtes d'Afrique. *Bull. Soc. Hist. Nat. Afr. Nord* 33: 7–14.

Fiorentini, L., P.Y. Dremeire, I. Leonori, A. Sala and V. Palumbo. 1999. Efficiency of the bottom trawl used for the Mediterranean international trawl survey (MEDITS). *Aquat. Living Resour.* 12: 187–205.

Fornós, J.J. and W.M. Ahr. 1997. Temperate carbonates on a modern, low-energy, isolated ramp; the Balearic platform, Spain. *J. Sediment. Res.* 67: 364–373.

Fornós, J.J., E. Ballesteros, C. Massuti and A. Rodríguez-Perea. 1988. Red algae sediments in the Balearic shelf. *Rapp. Proc. Verb. Comm. Int. Mer Médit.* 31: 86.

Foster, M.S. 2001. Rhodoliths: Between rocks and soft places. *J. Phycol.* 37: 659–667.

García-Muñoz, J.E., M.E. Manjón-Cabeza and J.E. García-Raso. 2008. Decapod crustacean assemblages from littoral bottoms of the Alboran Sea (Spain, west Mediterranean Sea): Spatial and temporal variability. *Sci. Mar.* 72: 437–449.

Gautier, Y. and J. Picard. 1957. Bionomie du banc de Magaud. *Recl. Trav. Stn. Mar. Endoume, France* 12: 28–40.

Giaccione, G. 1967. Popolamenti a Laminaria rodriguezii Bornet sul Banco Apollo dell'isola di Ustica (Mar Tirreno). *Nova Thalassia* 3: 1–9.

Giaccione, G. 1971. Contributo allo studio dei popolamenti algali del Basso Tirreno. *Ann. Univ. Ferrara IV* 17–43.

Giaccione, G. 1972. Struttura, ecologia e corologia dei popolamenti a Laminaria dello stretto di Messina e del mare di Alboran. *Mem. Biol. Mar. Oceanogr.* 2: 37–59.

Giaccione, G. 1973. Ecologie et chorologie des Cystoseira de Méditerranée. *Rapp. Comm. Int. Explor. Sci. Mer Médit.* 22: 49–50.

Grall, J. and M. Glémarec. 1997. Biodiversité des fonds de maërl en Bretagne: Approche fonctionnelle et impacts anthropiques. *Vie Milieu* 47: 339–349.

Huvé, H. 1954. Contribution à l'étude des fonds à Peyssonnelia polymorpha (Zan.) Schmitz de la région de Marseille. *Recl. Trav. Stn. Mar. Endoume, France* 12: 119–136.

Jacquotte, R. 1961. Affinités des peuplements des fonds de maërl de Méditerranée. *Rapp. Proc. Verb. Comm. Int. Mer Médit.* 16: 1.

Jacquotte, R. 1962. étude des fonds de maërl de Méditerranée. *Recl. Trav. Stn. Mar. Endoume, France* 26: 141–235.

Kamenos, N.A., P.G. Moore and J.M. Hall-Spencer. 2004. Nursery-area function of maërl grounds for juvenile queen scallops *Aequipecten opercularis* and other invertebrates. *Mar. Ecol. Prog. Ser.* 274: 183–189.

Klein, J.C. and M. Verlaque. 2009. Macroalgal assemblages of disturbed coastal detritic bottoms subject to invasive species. *Estuar. Coast. Shelf Sci.* 82: 461–468.

Kruskal, J.B. and M. Wish. 1978. *Multidimensional Scaling*. Sage Publications, Newbury Park, CA. pp. 93.

Laborel, J., J.M. Pérès, J. Picard and J. Vacelet. 1961. étude directe des fonds des parages de Marseille de 30 à 300 m avec la soucoupe plongeante Cousteau. *Bull. Inst. Océanogr. Monaco* 1206: 1–16.

Massuti, E. and O. Reñones. 2005. Demersal resource assemblages in the trawl fishing grounds off the Balearic Islands (western Mediterranean). *Sci. Mar.* 69: 167–181.

Massuti, E., O. Reñones, A. Carbonell and P. Oliver. 1996. Demersal fish communities exploited on the continental shelf and slope off Majorca (Balearic Islands, NW Mediterranean). *Vie Milieu* 46: 45–55.

Mazza, A. 1903. Aggiunta alla flora marina del Golfo di Napoli. *Nuova Notarissia* 18: 97–105.

Miller, Y., G. Schmiedt, C. Betzler, M. Römer, D. Jaramillo-Vogel and M. Sicca. 2009. Distribution of recent foraminifera in shelf carbonate environments of the Western Mediterranean Sea. *Mar. Micropaleontol.* 73: 207–225.

Molinier, R. 1956. Les fonds à laminaires du <<Grand Banc>> de Centuri (Cap Corse). *C. R. Acad. Sci. Paris* 342: 939–941.

Molinier, R. 1960. étude des biocénoses marines du Cap Corse. *Vegetatio* 9: 121–192.

Ordines, F. and E. Massuti. 2009. Relationships between macro-epibenthic communities and fish on the shelf grounds of the western Mediterranean. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 19: 370–383.

Pérès, J.M. 1985. History of the Mediterranean biota and the colonization of the depths. *In: (R. Margalef, ed.) Western Mediterranean*. Pergamon, Oxford. pp. 198–232.

Pérès, J.M. and J. Picard. 1963. Aperçu sommaire sur les peuplements marins benthiques entourant l'île de Port-Cros. *Terre Vie* 110: 336–448.

Pérès, J.M. and J. Picard. 1964. Nouveau manuel de bionomie benthique de la Mer Méditerranée. *Recl. Trav. Stn. Mar. Endoume, France* 31: 3–137.

Piazzì, L., G. Pardi and F. Cinelli. 2003. Structure and temporal dynamics of a macroalgal assemblage associated with a rhodolith bed of the Tuscan Archipelago. *Att. Soc. Tosc. Sci. Nat.* 109: 5–10.

Piazzì L., D. Balata and F. Cinelli. 2004. Species composition and morphological groups of macroalgal assemblages around Gorgona Island (north-western Mediterranean Sea). *Cryptogam. Algol.* 25: 19–38.

Picard, J. 1965. Recherches qualitative sur les biocénoses marines des substrats meubles drageables de la région marseillaise. *Recl. Trav. Stn. Mar. Endoume, France* 52: 1–160.

Potter, I.C., D.J. Bird, P.N. Claridge, K.R. Clarke, G.A. Hyndes and L.C. Newton. 2001. Fish fauna of the Seven Estuary and are there long-term changes in the recruitment patterns of the main marine species correlated? *J. Exp. Mar. Biol. Ecol.* 258: 15–37.

Rodríguez-Femenías, J.J. 1889. Algas de las Baleares. *Vie Milieu* 33: 141–235.

Salat, J. and J. Font. 1985. Masses d'aigua i circulació a la Mediterrània. *In: (J. Cardelús, director) L'oceànografia – Introducció a l'ecologia marina mediterrània*. Col lecció de Quaderns d'Ecològia Aplicada. Diputació de Barcelona, Barcelona. pp. 61–98.
Serio, D. and F. Pizzuto. 1990. Su un popolamento a *Vidalia volubilis* (L.) J.Ag. (Ceramiales, Rhodophyta) del litorale di Pozzillo (Catania). *Boll. Acc. Gioenia Sci. Nat.* 23: 399–414.

Serio, D. and F. Pizzuto. 1992. Sul popolamento a *Osmundaria volubilis* (L.) Norris del litorale di Pozzillo (Catania): Fenologia e periodismo. *Boll. Acc. Gioenia Sci. Nat.* 25: 307–323.

Steller, D.L., R. Riosmena-Rodríguez, M.S. Foster and C.A. Roberts. 2003. Rhodolith bed diversity in the Gulf of California: The importance of rhodolith structure and consequences of disturbance. *Aquat. Conserv: Mar. Freshw. Ecosyst.* 13: S5–S20.

UNEP/IUCN/GIS Posidonia. 1990. *Livre rouge “Gerard Vuignier” des végétaux, peuplements et paysages marins menacés de Méditerranée.* MAP Technical Reports Series No. 43. UNEP, Athens. pp. 250.

UNEP-MAP-RAC/SPA. 2008. *Action plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea.* RAC/SPA ed., Tunis. pp. 21.

Vives, F. and J.L. López-Jurado. 1988. Les copépodes des îles Balears en rapport avec les masses d’eau. *Rapp. Comm. Int. Mer. Medit.* 31: 234.