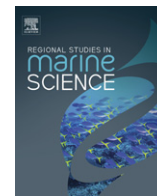




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# Maximising MEDITS: Using data collected from trawl surveys to characterise the benthic and demersal assemblages of the circalittoral and deeper waters around the Maltese Islands (Central Mediterranean)

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## HIGHLIGHTS

- Deep-water benthic assemblages around Malta are characterised for the first time.
- Four well-defined assemblages of benthic and demersal species were identified.
- Depth had a clear influence on community structure, species richness and abundance.
- MEDITS data provided valuable insights in the absence of dedicated benthic mapping.

## ARTICLE INFO

## Article history:

Received 23 May 2015

Received in revised form

17 July 2015

Accepted 20 July 2015

Available online xxxx

## Keywords:

Sicilian Channel

Malta

Biocoenoses

Community structure

Megabenthos

Mediterranean International Trawl Survey

GFCM GSA 15

## ABSTRACT

Data from MEDITS trawl surveys in the waters surrounding the Maltese Islands were analysed to characterise the benthic and demersal assemblages of the central Mediterranean, which are only poorly known, hampering Maltese authorities in meeting legislative obligations. A total of 147 benthic species and 98 demersal species were identified. These formed four well-defined assemblages, whose structure and composition were related to depth. Total species richness and abundance of both demersal and benthic species decreased with depth. The most abundant structuring epibenthic species which characterised the identified assemblages were the tall sea pen *Funicularia quadrangularis* (present at depths of ca. 50–700 m), the red sea pen *Pennatula rubra* (ca. 100–450 m), the hydroids *Lytocarpia myriophyllum* (ca. 100–250 m) and *Nemertesia* sp. (ca. 100–600), the soft coral *Alcyonium palmatum* (ca. 100–400 m), and the anemone *Actinauge richardi* (ca. 100–600 m). These results illustrate how, in the absence of dedicated benthic mapping studies, MEDITS data can be used to provide preliminary information that would not otherwise be available.

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## 1. Introduction

In order to address the problems caused by anthropogenic pressures on marine environments and the conflicts between multiple users competing for space and resources, environmental policies are increasingly emphasising the need for a holistic approach to the management of marine biological resources. An example of this is the ‘ecosystem approach’, which has been widely advocated since its adoption as an integral concept of the Convention on Biologi-

cal Diversity at the Earth Summit in Rio in 1992 (Beaumont et al., 2007; Borja et al., 2008; Stelzenmüller et al., 2012).

In many parts of the Mediterranean, information on marine biotic assemblages is fragmented, and baseline habitat maps are rarely available. Yet, without basic knowledge on seabed habitats and their distribution, on assemblages, and about species biology (distribution, abundance, habitat preferences, life-cycles) in the area, it is not possible to improve spatial planning in general, or strategic planning of particular human activities when there are competing demands (e.g. fishing, bunkering, wind energy generation, tourism, nature conservation) in particular (Connor et al., 2004; Bianchi et al., 2012). Additionally, information on benthic biocoenoses is essential to gauge the successful implementation of legislation aimed at the attainment of good environmental status through the sustainable use and conservation

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of marine biodiversity. Examples of such legislation include the Habitats Directive (Directive 1992/43/EC), the Mediterranean Regulation (EC 1967/2006), the Integrated Maritime Policy (IMP, COM (2007) 575), the Marine Strategy Framework Directive (MSFD, 2008/56/EC) and the Directive establishing a framework for Maritime Spatial Planning (Directive 2014/89/EU). This last, very recent regulation (23rd July 2014) on maritime spatial planning has the potential to improve decision-making by providing a framework to analyse competing human activities to manage their impact on the marine environment, and as such, is one of the core components of the EU Sustainable Development Strategy (European Commission, 2008). To be effectively implemented, all these legislative instruments require biocoenotic data.

In the central Mediterranean, particularly within the General Fisheries Commission (GFCM) Geographical Sub-Area (GSA) 15, knowledge on the biotic assemblages of deep areas is presently limited. In the case of the Maltese Islands, despite their position close to the meeting-point of two Mediterranean biogeographical regions (the west and east biozones), and despite them being a strategic locality ideal to monitor changes in biodiversity patterns in the Mediterranean, the benthic habitats of the deeper waters around the islands remain some of the least studied areas in the entire Mediterranean. While good habitat information is available for shore and nearshore ecosystems (summarised in the initial assessment report on benthic habitats published by the Maltese authorities as part of the implementation of the EU MSFD ([www.mepa.org.mt/water-msfd](http://www.mepa.org.mt/water-msfd))), equivalent data on the biocoenoses of circalittoral and deeper areas are still lacking, except for a pilot study that was carried out in this area (Camilleri et al., 2008). Other than this, data that exist are fragmented and were generated almost incidentally as a by-product of scientific projects and Environmental Impact Assessments (Dimech et al., 2004; ADI Associates, 2005; Borg et al., 2005; Schembri et al., 2007; Sciberras et al., 2009; Taviani et al., 2009). Such is the fragmentation and lack of access to existing data that there is a case where a biocoenotic map has been completed for the central Mediterranean region, omitting the 25 nautical mile Maltese Fisheries Management Zone (FMZ) around the Maltese Islands (s.v. Fiorentino et al., 2004).

Obtaining information on habitats in this area is neither easy nor cheap, particularly for the deeper areas where costly dedicated surveys would be required. However, some data are already available through regular surveys held within GSA 15 as part of the Mediterranean International Trawl Survey (MEDITS) programme, which is obligatory for all EU Mediterranean Member States. Its purpose is to produce basic information on benthic and demersal species of the continental shelves and along the upper slopes at a regional scale in the Mediterranean (Bertrand et al., 2002). The programme aims at conducting co-ordinated bottom trawling surveys in order to contribute annual data on population distribution, relative abundance, and demographic structure (length distributions, maturity stages, weights, etc.) of demersal fisheries resources.

Despite certain difficulties associated with using MEDITS data (such as the limited number of stations that are sampled and the lack of seasonality), the collection of data on different species and their abundance through MEDITS surveys provides a unique opportunity to increase knowledge of the benthic and demersal assemblages and their distribution within the GSA 15 area. It is therefore relevant to maximise the use of available MEDITS biotic data until dedicated benthic mapping surveys become possible. Such an approach will enable maximum use of available resources, ensure management decisions are based on the best biological data available, and thus aid the Maltese authorities in meeting legislative requirements.

Many of the studies undertaken so far using MEDITS data have focused on demersal assemblages. This is probably a consequence of the MEDITS protocol itself, for three reasons: (1) MEDITS surveys

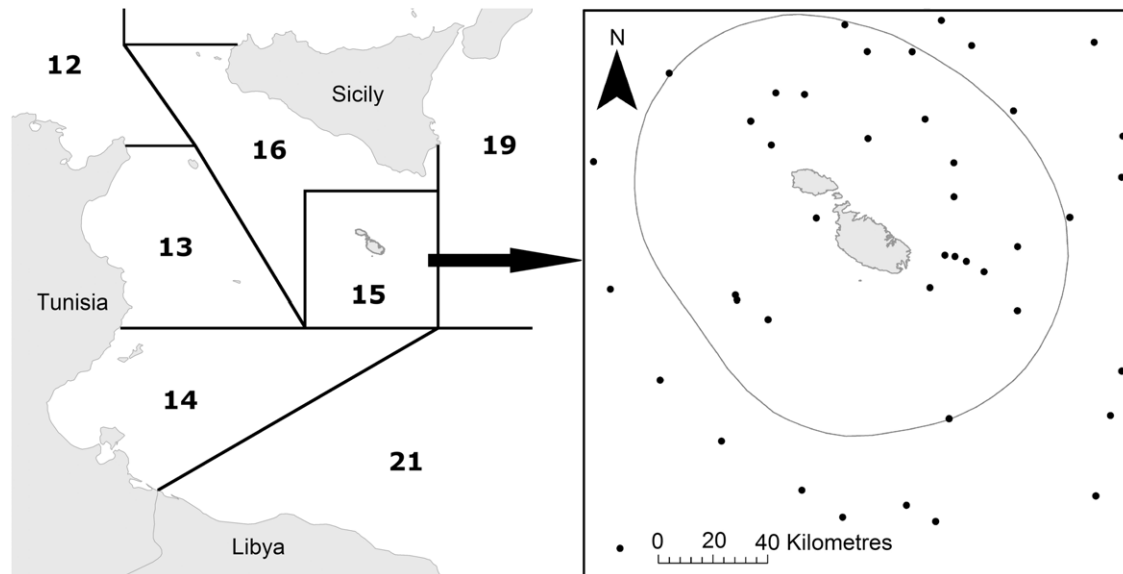
are designed for catching demersal species, and therefore, although benthic species are also sampled in the process, data on their abundance is best considered to be semi-quantitative and biased in terms size, since the samples consist mostly of megafauna; (2) the MEDITS protocol does not require counting of non-commercial species, with the exception of a few species of elasmobranchs, and such non-commercial species typically form part of the benthos (e.g. non-cephalopod molluscs, echinoderms, polychaetes, cnidarians, and sponges); (3) according to the MEDITS protocol, all species should be identified on board, which is not feasible for some groups that are taxonomically difficult or where microscopic examination is needed to differentiate between morphologically similar species.

In the present study we utilised data generated through the MEDITS programme to characterise the deep sea benthic and demersal assemblages of GSA 15, and to analyse their spatial and bathymetric distribution. We also assessed whether information provided from MEDITS surveys can be maximised by doing additional work on the benthic component for biocoenotic characterisation and mapping. Using these data, we illustrate how in the absence of dedicated benthic mapping studies, MEDITS data can be used to provide information that would not otherwise be available. To our knowledge, this is the first time that this has been attempted in GSA 15, and it thus provides a unique opportunity to test whether benthic assemblages have distribution patterns similar to those of demersal ones or not, which has implications on the utility of past (or future) studies on deep-water communities focusing primarily on demersal assemblages.

## 2. Materials and methods

This study was undertaken within the GFCM GSA 15 (Fig. 1). Samples were collected during bottom trawl surveys undertaken in 2009 and 2010 as part of the ongoing MEDITS programme (Bertrand et al., 2002). Each year, hauls were made at 43 different stations (Table 1) following the standard MEDITS protocol (MEDITS Working Group, 2013). The stations were proportionally distributed among four depth strata (51–100, 101–200, 201–500, 501–800 m); within each stratum, the position of the stations was selected randomly but remained constant in both years. All hauls were undertaken using bottom otter trawl nets with standard dimensions (IFREMER GOC 73: width 22 m, height of vertical opening 2 m, length 40 m, stretched mesh size at cod-end 20 mm; Fiorentini et al., 1999). The hauls had a duration of 30 min on bottoms shallower than 200 m depth and 60 min on bottoms deeper than 200 m; trawl speed was of ca. 3 knots. The exact start and end positions and depths, trawl speed and duration were recorded; these were then used to obtain the average position and sampling depth for each station. Indicative information on bottom-type at each station was derived from nautical charts.

The entire biological component from each haul was sorted on board and all fish, crustaceans and cephalopods (MEDITS faunistic categories A, B and C) were identified and counted. According to the MEDITS protocol, recording the number of individuals for other non-target species (MEDITS faunistic categories D and E) is not mandatory (see MEDITS Working Group, 2013), and on-board counting of such species is not normally undertaken during MEDITS surveys. These faunal groups were therefore stored (frozen on board and subsequently preserved in 10% formalin) for later analysis. When the volume of this non-target fraction was relatively small, the entire sample was stored. When the volume of the non-target fraction was too large to be retained in its entirety, a representative sub-sample of known volume, taken at random from the bulk haul, was collected. In such cases, the ratio of the total sample volume and sub-sample volume was recorded to enable data extrapolation. These samples were subsequently processed in the laboratory and all individuals were identified to the lowest possible



**Fig. 1.** Map showing the boundaries of the General Fisheries Commission (GFCM) Geographical Sub-Areas (GSA) in the central Mediterranean, and positions of the stations sampled within GSA 15 (inset) as part of the 2009 and 2010 MEDITS surveys (black dots). The extent of the Maltese 25 nautical mile Fisheries Management Zone is also shown (oval surrounding the Maltese Islands).

**Table 1**

List of stations in order of increasing mean sampling depth, together with indicative information on bottom-type (as indicated in nautical charts).

Station	Mean depth (m)	Bottom-type	Station	Mean depth (m)	Bottom-type
M43	74	Sand	M31	324	Mud
M44	77	Sand	M76	364	Mud
M46	77	Sand	M80	416	Mud
M47	80	Sand	M11	431	Mud
M49	84	Sand	M19	435	Mud
M37	91	Muddy sand	M70	437	Mud
M34	103	Muddy sand with shells	M82	448	Mud
M57	109	Sand	M74	465	Mud
M42	113	Mud with shells	M72	521	Mud
M55	125	Mud	M71	526	Mud
M54	127	Mud	M24	544	Clayey mud
M45	129	Mud	M25	564	Clayey mud
M40	131	Mud with shells	M60	602	Mud
M39	134	Mud	M63	605	Mud
M83	137	Mud	M22	606	Clayey mud
M75	144	Mud with shells	M65	611	Mud
M36	145	Mud with shells	M23	616	Clayey mud
M35	172	Mud	M14	620	Mud
M79	172	Sandy mud	M21	633	Clayey mud
M05	185	Sandy mud	M15	676	Clay
M32	231	Sandy mud	M18	683	Clay
M10	273	Mud			

taxon and enumerated. In the case of macrophytes, enumeration was generally not possible due to fragmentation of specimens during sampling; *Codium bursa* was an exception to this so this species was included in the analyses.

Standardised abundance (or density) measures were obtained by converting the raw catch data to number of individuals per km<sup>2</sup>, based on the area trawled during each haul. Each species was classified into one of two categories ('benthic' vs. 'demersal') according to its primary mode of life, based on personal knowledge on the biology of the species and through consulting reference databases (e.g. Froese and Pauly, 2015; Jebb and Roper, 2005, 2010; Jebb et al., 2014). Strictly pelagic species (e.g. *Engraulis encrasicolus* and *Histioteuthis* spp.) as well as benthopelagic species (e.g. *Hoplostethus mediterraneus* and *Coelorinchus caelorhincus*) were removed from the dataset. Analyses were initially carried out separately for the two years. Similar outcomes were obtained, so species-abundance data collected from the same station in

different years were treated as temporal (annual) replicates and averaged; further analyses were based on the averaged dataset. Preliminary comparisons among stations were made based on measures of species richness and standardised abundance/density. These univariate analyses were carried using SPSS v20 software (Statistical Package for Social Sciences, SPSS Inc.).

Multivariate analyses were subsequently carried out to study differences in assemblage structure between stations. A similarity matrix was constructed from the species-station dataset using the Bray–Curtis similarity index, based on square-root transformed data. This index was selected since it provides an intuitive measure of ecological similarity (Clarke, 1993; Legendre and Legendre, 1998). The square-root transformation was applied to down-weight the importance of highly-abundant species, thus allowing species of intermediate abundance to also contribute to the similarity calculations (Clarke and Green, 1988). A group-averaging cluster algorithm was employed to produce a dendrogram grouping stations

into distinct clusters, while ordination plots obtained from non-metric multidimensional scaling (nMDS) were used to explore station grouping patterns independently of the cluster analyses. These procedures were repeated starting with the entire species dataset, and sub-sets consisting of demersal or benthic species only. Correlations between the similarity matrices obtained for the different (non-interdependent) species sub-sets were tested using a non-parametric form of the Mantel test (RELATE). The main species contributing to differences between clusters of stations which consistently grouped together were then analysed using the Similarity Percentage procedure (SIMPER; Clarke, 1993). Finally, the analyses were also repeated using other initial data transformations (untransformed, fourth-root, presence/absence) in order to assess the effect of transformation on the station grouping patterns. These multivariate analyses were undertaken using PRIMER v6.1 (Plymouth Routines in Multivariate Ecological Research, PRIMER-E Ltd.).

### 3. Results

Throughout the two-year survey period, a total of ca. 166,000 individuals (based on extrapolation when sub-sampling was undertaken) belonging to 245 species were recorded. Of these, 147 species were benthic while the remaining 98 species were demersal. Actinopterygii was the dominant taxonomic group in terms of species richness (63 species) and abundance (96,000 individuals). Other main taxonomic groups recorded during the surveys included Crustacea (52 species), Mollusca (42 species), Echinodermata (26 species), Elasmobranchii (23 species) and Cnidaria (16 species), while a few sponges, bryozoans and tunicates were also present in the hauls. A classified list of all recorded species, together with their mean density, frequency of occurrence and recorded depth range is provided in Table 2.

Total species richness recorded from different stations ranged between 20 and 62 species, with a mean ( $\pm$ SD) of  $37.9 \pm 11.2$  species. On average, demersal species had a higher richness (mean =  $25.4 \pm 7.5$  SD) than benthic species (mean =  $12.4 \pm 7.3$  SD). Overall species richness was inversely related to sampling depth (Pearson's  $r = -0.80$ ,  $p < 0.001$ ; Fig. 2(a)). Similar trends were also observed when considering richness of demersal ( $r = -0.55$ ,  $p < 0.001$ ) and benthic ( $r = -0.66$ ,  $p < 0.001$ ) taxa separately, although the strength of the association was slightly lower in both cases. Standardised abundance varied significantly between stations, ranging between 1,799 and 102,025 ind/km<sup>2</sup> (mean =  $28,293 \pm 22,961$  SD ind/km<sup>2</sup>). The density of individuals also decreased with depth ( $r = -0.57$ ,  $p < 0.001$ ) even if substantial variation in abundance recorded from stations having similar depths was present (Fig. 2(b)). Similar results but with a weaker correlation between abundance and depth were also apparent for sub-sets of demersal ( $r = -0.34$ ,  $p < 0.05$ ) and benthic ( $r = -0.44$ ,  $p < 0.01$ ) species.

Cluster analyses based on square-root transformed abundance data yielded similar clustering patterns irrespective of the species set/sub-set used for the analysis (Fig. 3); the two sets of among-station relationships (similarity matrices) obtained using benthic and demersal species separately were highly correlated (RELATE: Spearman's  $\rho = 0.71$ ;  $p < 0.001$ ). Four main clusters (groups A–D) were obtained when the analyses were based on all species or only on demersal fauna. These four clusters were also evident in the dendrogram generated through cluster analysis based on benthic species only, but in this case a fifth cluster (group E) was also obtained. The four main clusters seen in all three dendrograms were clearly associated with bottom depth, with groups of stations that consistently clustered together having depth ranges of 74–84 m (group A), 91–185 m (group B), 324–544 m (group

C) and 605–683 m (group D). On the other hand, the five stations comprising group E ranged from 231 to 602 m in depth.

Eight stations were included in different clusters in the dendrograms, depending on whether all species, benthic species or demersal species only, were considered (Fig. 3). Five of these stations represent the fifth cluster (group E) obtained when the analysis was based on benthic species only. The other three stations (M34, M57 and M25) did not consistently group in the same clusters. The nMDS ordination plots indicated a gradual change in assemblage structure with increasing depth (rather than very distinct clusters), and these three stations represented assemblages intermediate between those of two of the clusters (Fig. 4). Stations M43 and M57 had depths of 103–109 m (intermediate between groups A and B), while station M25 had a depth of 564 m (intermediate between groups C and D). A comparison of the nMDS plots obtained for different species sub-sets indicated that differences between the deeper water stations comprising groups C, D and E were less marked in the case of benthic species, and these three groups can be considered to form a single super-cluster (Figs. 3(b) and 4(b)). The station grouping pattern obtained through cluster analyses was generally unaffected by different pre-transformations of abundance data; the core stations of each group clustered together irrespective of the transformation used.

Although no detailed data on the granulometric characteristics of the seafloor in the area is available, indicative information derived from nautical charts (see Table 1) shows that coarse material is present at the shallowest stations, while muddy bottoms characterise most of the other stations with a predominance of clayey sediments in deeper (>550 m) sites. When considering the geographic position of the stations, spatial clustering is evident, but is mostly a result of the bathymetry of the GSA15 area (Fig. 5). Thus, group A and B stations occur mostly to the northeast and east of the Maltese Islands due to a wide shelf <200 m in depth present in the area, while group D stations are located within the Malta Trough to the west of the islands where depths >600 m are found. On the other hand, spatial clustering is less evident in the case of group C stations because intermediate depths (ca. 250–550 m) occur in more than one area within GSA 15, while the five stations comprising group E (in the case of benthic species) also lack spatial aggregation.

Several species occurred over a wide depth zone, being recorded from more than one of the station groups defined by cluster analyses. However, each group was characterised by its own particular assemblage structure in terms of both benthic and demersal species (Tables 3 and 4). Average similarity for the groups ranged between 28%–45% when considering benthic species and 49%–66% for demersal species. Between-group dissimilarities were higher than 65% in all cases, with the highest dissimilarities noted between groups A and D. The shallower stations (group A) were mostly characterised by a high density of cidarids (*Cidaris cidaris* and *Stylocidaris affinis*) and other echinoderms, combers (*Serranus* spp.) and red mullets (*Mullus* spp.). The abundance of echinoderms decreased with depth, with Group B stations being dominated by the longspine snipefish *Macroramphosus scolopax*, and to a lesser extent gurnards (*Lepidotrigla* spp.), European hake (*Merluccius merluccius*), boarfish (*Capros aper*) and deep-water rose shrimp (*Parapenaeus longirostris*). In deeper waters, crustaceans became more dominant: group C stations were mainly characterised by the decapods *P. longirostris*, *Plesionika* spp. and *Nephrops norvegicus*, together with the shortnose greeneye (*Chlorophthalmus agassizi*), while deeper still, the giant red shrimp *Aristaeomorpha foliacea* was characteristic of group D stations. The five stations which clustered together as group E in analyses based on benthic species mainly differed from other deep (>200 m) stations by having higher abundances of *C. cidaris* and the anemone *Actinauge richardi*.



**Table 2**

Classified list of species recorded during the 2009 and 2010 MEDITS surveys carried out in GFCM GSA 15, with mean density (Av.D), frequency of occurrence (Freq.) and recorded depth range (Depth); only a single depth value is shown for species that were only recorded from a single haul.

(a) Benthic species							
Taxon	Av.D (ind/km <sup>2</sup> )	Freq. (%)	Depth (m)	Taxon	Av.D (ind/km <sup>2</sup> )	Freq. (%)	Depth (m)
<b>Chlorophyta</b>				<b>Cnidaria</b>			
<i>Codium bursa</i>	17.6	3.3	75–131	<b>Anthozoa</b>			
<b>Porifera</b>				<i>Actinauge richardi</i>	17.5	17.8	91–604
<i>Agelas oroides</i>	0.4	2.2	81–621	<i>Alcyonium palmatum</i>	3.9	16.7	91–361
<i>Dysidea fragilis</i>	0.2	1.1	171	<i>Callogorgia verticillata</i>	0.5	2.2	130–134
<i>Erylus deficiens</i>	2.0	2.2	75–79	<i>Caryophyllia ?calveri</i>	3.4	4.4	110–547
<i>Halichondria</i> sp.	0.3	1.1	79	<i>Desmophyllum dianthus</i>	0.1	1.1	568
<i>Haliclona</i> spp.	4.0	3.3	75–81	<i>Epizoanthus</i> sp.	1.6	3.3	109–137
<i>Jaspis</i> sp.	1.8	1.1	75	<i>Funiculina quadrangularis</i>	324.4	36.7	75–680
<i>Poecillastra compressa</i>	0.3	1.1	79	<i>Gorgoniidae</i> sp.	0.8	1.1	133
<i>Rhizaxinella elongata</i>	0.5	2.2	127–130	<i>Isidella elongata</i>	1.1	6.7	113–687
<i>Spongia officinalis</i>	0.3	1.1	79	<i>Lophelia pertusa</i>	0.1	1.1	455
<i>Suberites</i> sp.	0.5	2.2	77–91	<i>Maasella edwardsi</i>	1.0	4.4	113–171
<i>Topsentia</i> sp.	0.3	1.1	79	<i>Pennatula rubra</i>	14.5	15.6	78–425
<b>Polychaeta</b>				<i>Pteroeides griseum</i>	2.4	3.3	109–144
<b>Aphroditidae</b> sp.	0.7	2.2	73–77	<b>Hydrozoa</b>			
<b>Sipuncula</b>				<i>Nemertesia ramosa</i>	0.4	2.2	113–604
<i>Aspidosiphon muelleri</i>	1.7	3.3	79–512	<i>Nemertesia</i> sp.	1.6	8.9	134–521
<i>Phascolosoma</i> sp.	0.2	2.2	475–615	<b>Crustacea</b>			
<i>Golfingia vulgaris</i>	0.3	1.1	79	<b>Amphipoda</b>			
<b>Mollusca</b>				<b>Aoridae</b> sp.	3.0	1.1	102
<b>Gastropoda</b>				<b>Lysianassidae</b> sp.	0.6	1.1	512
<i>Aporrhais pespelecani</i>	139.9	1.1	109	<i>Maera</i> sp.	3.5	1.1	75
<i>Aporrhais serresianus</i>	1.1	1.1	512	<i>Photis</i> sp.	10.2	1.1	79
<i>Bolinus brandaris</i>	15.1	1.1	125	<i>Socarnes filicornis</i>	0.2	1.1	77
<i>Calliostoma granulatum</i>	35.2	3.3	76–133	<b>Isopoda</b>			
<i>Crepidula unguiformis</i>	397.6	2.2	84–131	<i>Cirolana</i> sp.	11.3	3.3	76–127
<i>Euthria cornea</i>	1.1	1.1	361	<i>Cymodoce truncata</i>	25.8	5.6	75–446
<i>Fusinus rostratus</i>	204.1	1.1	79	<i>Stenosoma</i> sp.	10.2	1.1	79
<i>Fusinus</i> sp.	5.6	2.2	512–599	<b>Stomatopoda</b>			
<i>Fusiturrus similis</i>	28.0	1.1	109	<i>Squilla mantis</i>	1.3	2.2	91
<i>Galeodea echinophora</i>	55.3	13.3	91–542	<b>Decapoda</b>			
<i>Semicassis granulata</i>	15.1	1.1	125	<i>Alpheus glaber</i>	6.7	1.1	109
<i>Turritella communis</i>	251.8	1.1	109	<i>Anomura</i> sp.	25.5	1.1	76
<b>Bivalvia</b>				<i>Bathynectes maravigna</i>	1.0	4.4	542–680
<i>Acanthocardia echinata</i>	1.1	1.1	109	<i>Calappa granulata</i>	23.7	6.7	78–128
<i>Aequipecten opercularis</i>	1.5	1.1	77	<i>Calcinus tubularis</i>	2.5	1.1	440
<i>Anadara gibbosa</i>	0.9	1.1	125	<i>Dardanus calidus</i>	10.2	1.1	79
<i>Anomia ephippium</i>	1.6	4.4	78–521	<i>Galathea intermedia</i>	41.1	3.3	77–84
<i>Arca tetragona</i>	9.8	1.1	84	<i>Geryon longipes</i>	8.1	14.4	547–687
<i>Idas</i> sp.	0.1	1.1	475	<i>Goneplax rhomboides</i>	11.8	5.6	79–455
<i>Irus irus</i>	0.3	1.1	113	<i>Hippolyte</i> sp.	0.2	1.1	77
<i>Monia squama</i>	60.0	2.2	84–109	<i>Hormola barbata</i>	2.5	6.7	91–133
<i>Musculus subpictus</i>	0.2	1.1	77	<i>Inachus</i> sp.	20.4	1.1	79
<i>Palliolium incomparabile</i>	2.8	1.1	77	<i>Inachus thoracicus</i>	16.6	5.6	73–455
<i>Pseudamussium clavatum</i>	0.3	1.1	113	<i>Latreillia elegans</i>	3.3	5.6	113–143
<i>Venus casina</i>	1.4	2.2	109–127	<i>Liocarcinus corrugatus</i>	0.1	1.1	674
<i>Venus nux</i>	1.0	3.3	91–125	<i>Liocarcinus depurator</i>	0.5	1.1	449
<i>Venus verrucosa</i>	0.2	1.1	110	<i>Macropodia longipes</i>	0.6	3.3	134–361
<b>Cephalopoda</b>				<i>Macropodia</i> sp.	2.5	3.3	75–130
<i>Eledone cirrhosa</i>	1.0	4.4	221–541	<i>Medorippe lanata</i>	0.3	1.1	113
<i>Eledone moschata</i>	8.9	8.9	76–137	<i>Mumida intermedia</i>	0.8	3.3	361–449
<i>Macrotritopus defilippi</i>	0.4	2.2	127–475	<i>Munida</i> sp.	0.1	1.1	242
<i>Octopus salutii</i>	0.8	4.4	274–542	<i>Nephrops norvegicus</i>	208.0	44.4	221–680
<i>Octopus vulgaris</i>	22.5	12.2	73–171	<i>Pagurus alatus</i>	31.6	6.7	75–542
<i>Pteroctopus tetracirrhus</i>	1.9	6.7	304–620	<i>Pagurus carneus</i>	63.0	5.6	75–521
<i>Scaevurgus uniccirrhus</i>	20.0	31.1	76–599	<i>Pagurus species A</i>	1.8	2.2	73–78
<b>Echinodermata</b>				<i>Pagurus species B</i>	0.3	1.1	81
<b>Crinoidea</b>				<i>Paromola cuvieri</i>	0.2	1.1	594
<i>Antedon mediterranea</i>	4.1	1.1	73	<i>Philocheras ?echinulatus</i>	0.7	2.2	125–147
<i>Leptometra phalangi</i>	2.2	1.1	442	<i>Pisa armata</i>	21.9	3.3	73–81
<b>Asteroidea</b>				<i>Pisa</i> spp.	0.8	2.2	73–81
<b>Anseropoda</b> <i>placenta</i>	105.5	3.3	73–78	<i>Polycheles typhlops</i>	6.6	18.9	374–687
				<i>Processa</i> sp.	0.1	1.1	475
				<i>Sergestes</i> sp.	0.4	1.1	416
				<i>Spinolambrus macrochelos</i>	0.2	2.2	343–361

(continued on next page)

Table 2 (continued)

(a) Benthic species							
Taxon	Av.D (ind/km <sup>2</sup> )	Freq. (%)	Depth (m)	Taxon	Av.D (ind/km <sup>2</sup> )	Freq. (%)	Depth (m)
<i>Astropecten irregularis</i>	259.4	6.7	79–171	<b>Bryozoa</b>			
<i>Astropecten jonstoni</i>	14.7	3.3	91–147	<i>Disporella</i> sp.	0.4	1.1	77
<i>Astropecten</i> spp.	0.3	1.1	78	<b>Chordata</b>			
<i>Echinaster sepositus</i>	288.3	3.3	79–110	<b>Ascidiacea</b>			
<i>Hacelia attenuata</i>	315.7	7.8	73–143	<i>Ascidia mentula</i>	3.1	5.6	76–147
<i>Hymenodiscus coronata</i>	1.8	1.1	431	<i>Ascidiella aspersa</i>	2.6	1.1	133
<i>Luidia ciliaris</i>	307.7	2.2	78–79	<i>Ascidiella scabra</i>	13.1	7.8	76–134
<i>Marthasterias glacialis</i>	0.4	2.2	78–594	<i>Diazona violacea</i>	0.3	1.1	113
<i>Peltaster placenta</i>	419.5	14.4	73–678	<i>Polycarpa pomaria</i>	0.5	1.1	125
<i>Sclerasterias richardi</i>	0.2	1.1	143	<b>Actinopterygii</b>			
<i>Tethyaster subinermis</i>	14.9	11.1	73–604	<i>Callionymus</i> sp.	10.3	7.8	130–674
<b>Ophiuroidea</b>				<i>Lepadogaster lepadogaster</i>	2.8	1.1	442
<i>Astrospartus mediterraneus</i>	0.5	1.1	137	<i>Muraena helena</i>	0.8	1.1	81
<i>Ophiopsila annulosa</i>	3.0	1.1	102	<i>Solea</i> spp.	0.3	1.1	78
<i>Ophiothrix quinquemaculata</i>	0.2	1.1	173	<i>Synchiropus phaeton</i>	0.8	1.1	440
<i>Ophiura ophiura</i>	0.8	2.2	113–130	<i>Synodus saurus</i>	0.6	3.3	84–411
<b>Echinoidea</b>				<i>Trigloporus lastoviza</i>	73.3	11.1	75–113
<i>Centrostephanus longispinus</i>	863.5	16.7	73–171				
<i>Cidaris cidaris</i>	648.8	51.1	73–678				
<i>Echinus melo</i>	1.2	7.8	78–440				
<i>Genocidaris maculata</i>	0.4	1.1	77				
<i>Gracilechinus acutus</i>	4.4	11.1	102–678				
<i>Spatangus purpureus</i>	204.6	2.2	79–84				
<i>Stylocidaris affinis</i>	606.1	25.6	73–568				
<b>Holothuroidea</b>							
<i>Parastichopus regalis</i>	33.1	14.4	84–173				
(b) Demersal species							
Taxon	Av.D (ind/km <sup>2</sup> )	Freq. (%)	Depth (m)	Taxon	Av.D (ind/km <sup>2</sup> )	Freq. (%)	Depth (m)
<b>Mollusca</b>				<b>Chordata</b>			
<b>Cephalopoda</b>				<b>Actinopterygii</b>			
<i>Alloteuthis media</i>	71.0	14.4	78–613	<i>Anthias anthias</i>	11.2	6.7	125–144
<i>Alloteuthis subulata</i>	54.6	23.3	75–431	<i>Apogon imberbis</i>	0.5	1.1	91
<i>Illex coindetii</i>	48.6	40.0	75–542	<i>Argentina sphyraena</i>	1300.9	41.1	91–455
<i>Rossia macrosoma</i>	0.4	1.1	521	<i>Arnoglossus imperialis</i>	8.8	1.1	102
<i>Sepia elegans</i>	11.9	17.8	73–304	<i>Arnoglossus laterna</i>	18.3	14.4	78–137
<i>Sepia officinalis</i>	21.5	13.3	73–131	<i>Arnoglossus rueppelii</i>	4.1	8.9	76–431
<i>Sepia orbignyana</i>	170.0	40.0	73–455	<i>Arnoglossus thori</i>	1.0	2.2	73–81
Sepiolidae sp.	890.1	24.4	91–621	<i>Bathypterois dubius</i>	0.3	3.3	612–674
<i>Todaropsis eblanae</i>	108.7	44.4	75–680	<i>Benthocometes robustus</i>	0.1	1.1	455–455
<b>Crustacea</b>				<i>Blennius ocellaris</i>	5.3	11.1	78–132
<b>Decapoda</b>				<i>Boops boops</i>	158.9	26.7	76–190
<i>Aristaeomorpha foliacea</i>	288.6	31.1	425–687	<i>Callanthias ruber</i>	0.7	1.1	144
<i>Aristeus antennatus</i>	1.8	4.4	604–687	<i>Capros aper</i>	1527.9	50.0	91–639
<i>Chlorotocus crassicornis</i>	18.2	6.7	367–604	<i>Cepola macrophthalma</i>	32.3	16.7	102–181
<i>Macropipus tuberculatus</i>	14.0	14.4	91–680	<i>Chelidonichthys cuculus</i>	134.4	27.8	73–181
<i>Parapenaeus longirostris</i>	2778.4	75.6	91–687	<i>Chelidonichthys lucerna</i>	1.7	1.1	130
<i>Pasiphaea</i> spp.	264.7	14.4	242–680	<i>Chlorophthalmus agassizi</i>	4343.5	43.3	130–639
<i>Penaeus kerathurus</i>	11.3	3.3	109–131	<i>Citharus linguatula</i>	110.1	40.0	76–361
<i>Plesionika</i> spp.	531.6	47.8	78–687	<i>Conger conger</i>	1.8	8.9	125–678
<i>Solenocera membranacea</i>	1.2	2.2	449–455	<i>Coris julis</i>	0.3	1.1	81
<b>Chordata</b>				<i>Dactylopterus volitans</i>	0.3	1.1	73
<b>Elasmobranchii</b>				<i>Deltentosteus quadrimaculatus</i>	38.1	2.2	102–104
<i>Centrophorus granulosus</i>	2.0	5.6	440–621	<i>Echelus myrus</i>	7.2	16.7	91–599
<i>Dalatias licha</i>	0.3	3.3	615–628	<i>Epigonus denticulatus</i>	0.8	2.2	449–547
<i>Dasyatis centroura</i>	0.2	1.1	131	<i>Eutrigla gurnardus</i>	16.9	16.7	109–190
<i>Dasyatis pastinaca</i>	2.5	5.6	73–131	<i>Gaidropsarus mediterraneus</i>	0.2	2.2	542–612
<i>Dipturus oxyrinchus</i>	20.7	35.6	173–639	<i>Glossanodon leiglossus</i>	59.7	6.7	102–475
<i>Etmopterus spinax</i>	59.5	28.9	411–687	<i>Gnathophis mystax</i>	1.9	4.4	144–599
<i>Galeus melastomus</i>	360.4	45.6	304–687	<i>Helicolenus dactylopterus</i>	157.6	60.0	91–687
<i>Heptranchias perlo</i>	3.1	13.3	411–680	<i>Lepidorhombus boscii</i>	16.3	37.8	143–678
<i>Leucoraja circularis</i>	5.2	12.2	221–687	<i>Lepidorhombus whiffiagonis</i>	4.2	14.4	171–620
<i>Leucoraja fullonica</i>	0.1	1.1	272	<i>Lepidotrigla cavillone</i>	785.7	27.8	76–190
<i>Leucoraja melitensis</i>	11.8	11.1	171–568	<i>Lepidotrigla dieuzeidei</i>	320.7	22.2	76–272
<i>Mustelus asterias</i>	6.3	15.6	109–274	<i>Lesueurigobius suerii</i>	5.6	2.2	91–113
<i>Mustelus mustelus</i>	6.1	12.2	102–568	<i>Lophius budegassa</i>	17.3	56.7	81–621
<i>Mustelus punctulatus</i>	1.5	2.2	110–137	<i>Lophius piscatorius</i>	1.5	7.8	79–620
<i>Oxynotus centrina</i>	1.1	5.6	125–628	<i>Macroramphosus scolopax</i>	4025.5	37.8	91–617
<i>Raja clavata</i>	54.0	50.0	84–615	<i>Merluccius merluccius</i>	532.1	77.8	78–680
<i>Raja miraletus</i>	21.7	22.2	84–304	<i>Microchirus variegatus</i>	0.3	1.1	73
				<i>Molva dypterygia</i>	12.0	13.3	242–678
				<i>Mullus barbatus</i>	520.2	41.1	76–599

(continued on next page)

Table 2 (continued)

(a) Benthic species							
Taxon	Av.D (ind/km <sup>2</sup> )	Freq. (%)	Depth (m)	Taxon	Av.D (ind/km <sup>2</sup> )	Freq. (%)	Depth (m)
<i>Raja montagui</i>	0.4	3.3	272–542	<i>Mullus surmuletus</i>	218.0	34.4	73–639
<i>Raja radula</i>	0.3	1.1	78	<i>Nettastoma melanurum</i>	4.0	16.7	521–678
<i>Scyliorhinus canicula</i>	210.1	63.3	73–568	<i>Peristedion cataphractum</i>	264.2	47.8	125–620
<i>Squalus blainville</i>	29.4	31.1	104–568	<i>Sardinella aurita</i>	1.1	3.3	76–79
<i>Squalus uyato</i>	0.8	2.2	521	<i>Scorpaena elongata</i>	11.3	22.2	76–446
<i>Torpedo marmorata</i>	4.1	13.3	79–304	<i>Scorpaena notata</i>	2.3	1.1	79
<b>Holocephali</b>				<i>Scorpaena porcus</i>	2.3	2.2	75–81
<i>Chimaera monstrosa</i>	5.0	18.9	431–687	<i>Scorpaena scrofa</i>	114.1	4.4	128–455
				<i>Serranus cabrilla</i>	382.7	26.7	73–144
				<i>Serranus hepatus</i>	492.9	33.3	73–171
				<i>Sphoeroides pachygaster</i>	1.6	5.6	76–113
				<i>Symphurus nigrescens</i>	2.5	8.9	91–617
				<i>Trachinus draco</i>	0.8	2.2	73–78
				<i>Trigla lyra</i>	30.6	22.2	113–455
				<i>Uranoscopus scaber</i>	1.6	5.6	76–125

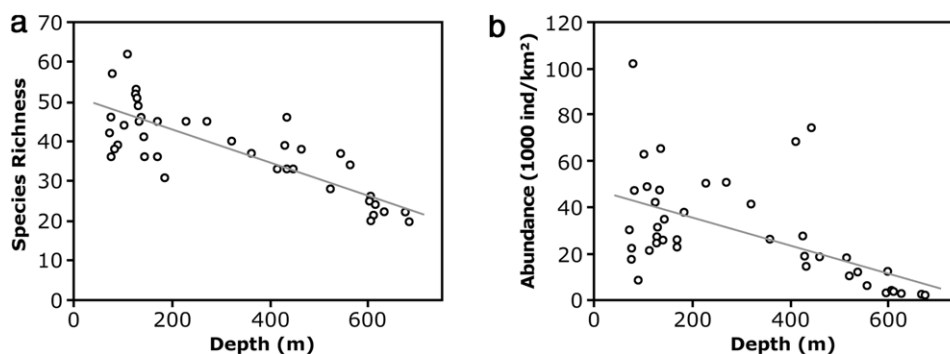


Fig. 2. (a) Richness–Depth and (b) Abundance–Depth correlation plots for biota sampled during the 2009 and 2010 MEDITS surveys within GFCM GSA 15.

#### 4. Discussion

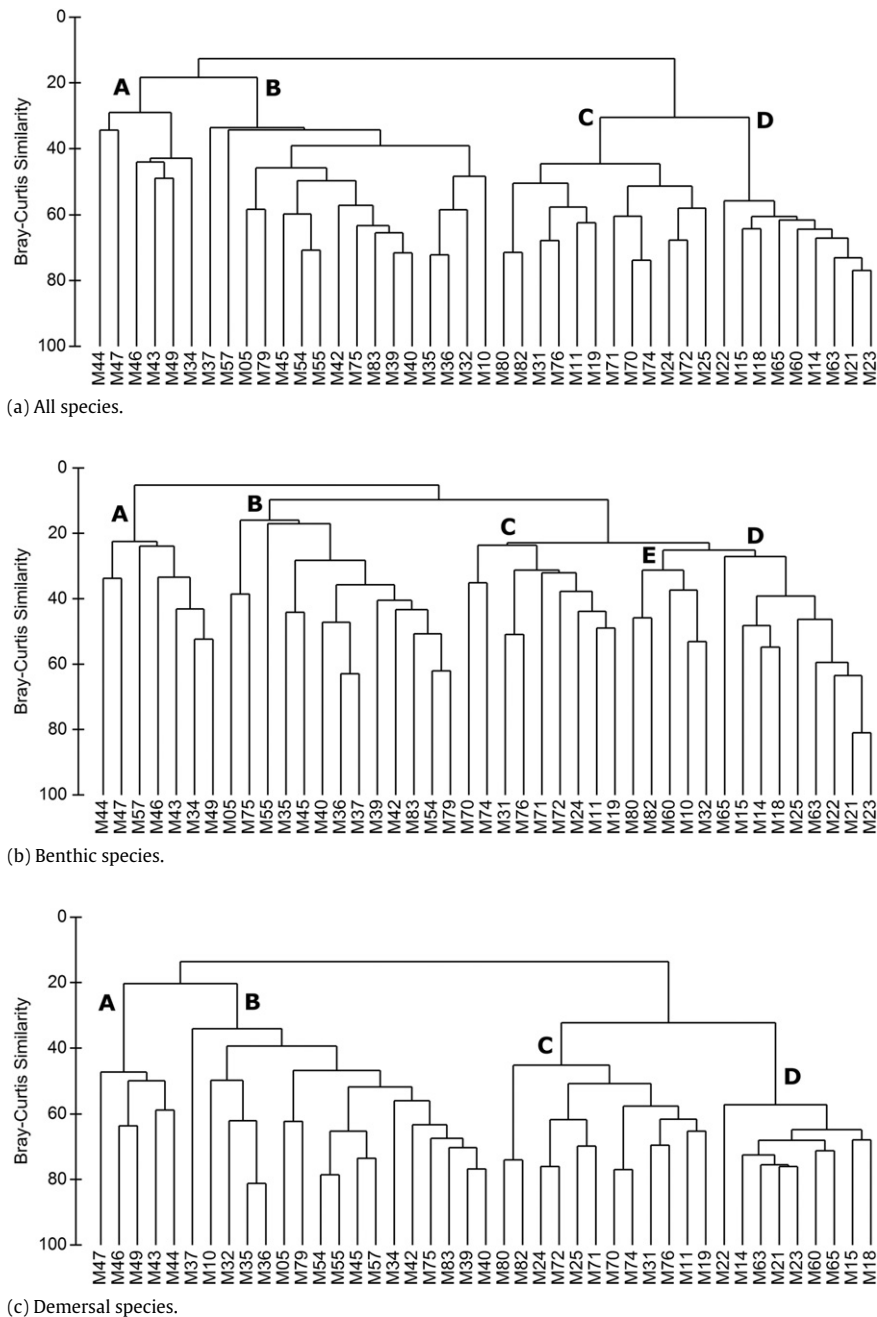
Characterisation of the deep sea assemblages of GSA 15 indicated four main station clusters when the analyses were based on all species or only on demersal fauna, while five clusters were obtained when the analyses were based on benthic fauna only. The distribution of these clusters was clearly influenced by depth. The species richness and total abundance of both demersal and benthic species in the assemblages also decreased with depth.

For demersal assemblages, a similar structuring pattern based on the influence of depth has been observed in several previous studies, including in the eastern Mediterranean (Labropoulou and Papaconstantinou, 2000; Kallianiotis et al., 2000, 2004), the Adriatic Sea (Ungaro et al., 1998), the Ligurian/Tyrrhenian Seas (Colloca et al., 2003; Biagi et al., 2002; Busalacchi et al., 2010; Mangano et al., 2013), the Sicilian Channel (Dimech et al., 2008), the Ionian Sea (D'Onghia et al., 2003; Politou et al., 2008), the Gulf of Lions (Gaertner, 2000), the Balearic Islands (Moranta et al., 1998; Massutí and Moranta, 2003), and the Spanish Mediterranean coast (Abelló et al., 1988; Demestre et al., 2000). This depth related pattern is due to a number of interacting biological and physical factors which change with depth, including light intensity, food availability, and temperature (see Cartes and Sardà, 1993; Cartes et al., 2009; Colloca et al., 2003; Stefanescu et al., 1993; Massutí et al., 2004).

The precise depth limits separating the assemblages vary between different studies, including those done in the Sicilian Channel and the nearby Ionian Sea. For instance, Dimech et al. (2008) found the demersal fishery resources on the muddy bottoms of Maltese trawling grounds to be stratified in four main depth ranges: the outer continental shelf (83–166 m), the shelf break (140–230 m), the shallow slope (270–440 m), and the deep slope

(466–701 m). D'Onghia et al. (2003) identified two major assemblages in the Ionian Sea, one on the upper slope (327–478 m) and one on the deep slope (513–757 m), with some separation between the intermediate (513–683 m) and deeper (597–757 m) stations of the deep slope. The lack of distinct, sharp changes in the composition of demersal communities and the resulting differences in the precise depth ranges obtained in different studies may be due to the presence of a patchy and complex array of habitats, as well as numerous transition regions between distinct biological communities (ecotones). However, differences could also be partly due to the sampling strategy, since practically all these studies were based on data obtained through trawl surveys. Samples collected by trawling may not accurately reflect small-scale habitat complexity since a haul can extend over ecotones, while the precise location of trawl survey stations may also vary between surveys held at different times. Thus, species present in samples and the resulting grouping of samples from such transition regions may vary from one survey to another.

Despite these differences in the precise depth ranges, the same species characterised the demersal assemblages within the Sicilian Channel and Ionian Sea. With the exception of the two benthopelagic fish, *Hoplosthetus mediterraneus* and *Coelorinchus caelorhincus*, which were not included in the present analysis, all the dominant species responsible for the assemblages identified by Dimech et al. (2008) were also found to be important species contributing to similarity in each of the four demersal species groups identified in the present study (groups A–D). Similarly, several of the species characterising cluster C in Maltese waters, including *Chlorophthalmus agassizii*, *Plesionika* sp., *Parapenaeus longirostris* and *Galeus melastomus*, were also dominant species on the upper slope off the Italian and Greek Ionian coasts (D'Onghia et al., 2003). Likewise, *Aristaeomorpha foliacea* and *Plesionika* spp. were dominant in the deep slope area off Greece (D'Onghia et al., 2003) and



**Fig. 3.** Dendrograms obtained via group-average cluster analyses, based on a similarity matrix constructed using the Bray–Curtis index on square-root transformed abundance data for (a) all species, (b) benthic species only, (c) demersal species only. Clusters are indicated by the letters A–E. Station groupings were generally consistent in the different dendrograms with the exception of five stations that formed a separate cluster (group E) when the analysis was based on benthic species only, and another three stations (M34, M57 and M25) that were included in different clusters in the different dendrograms.

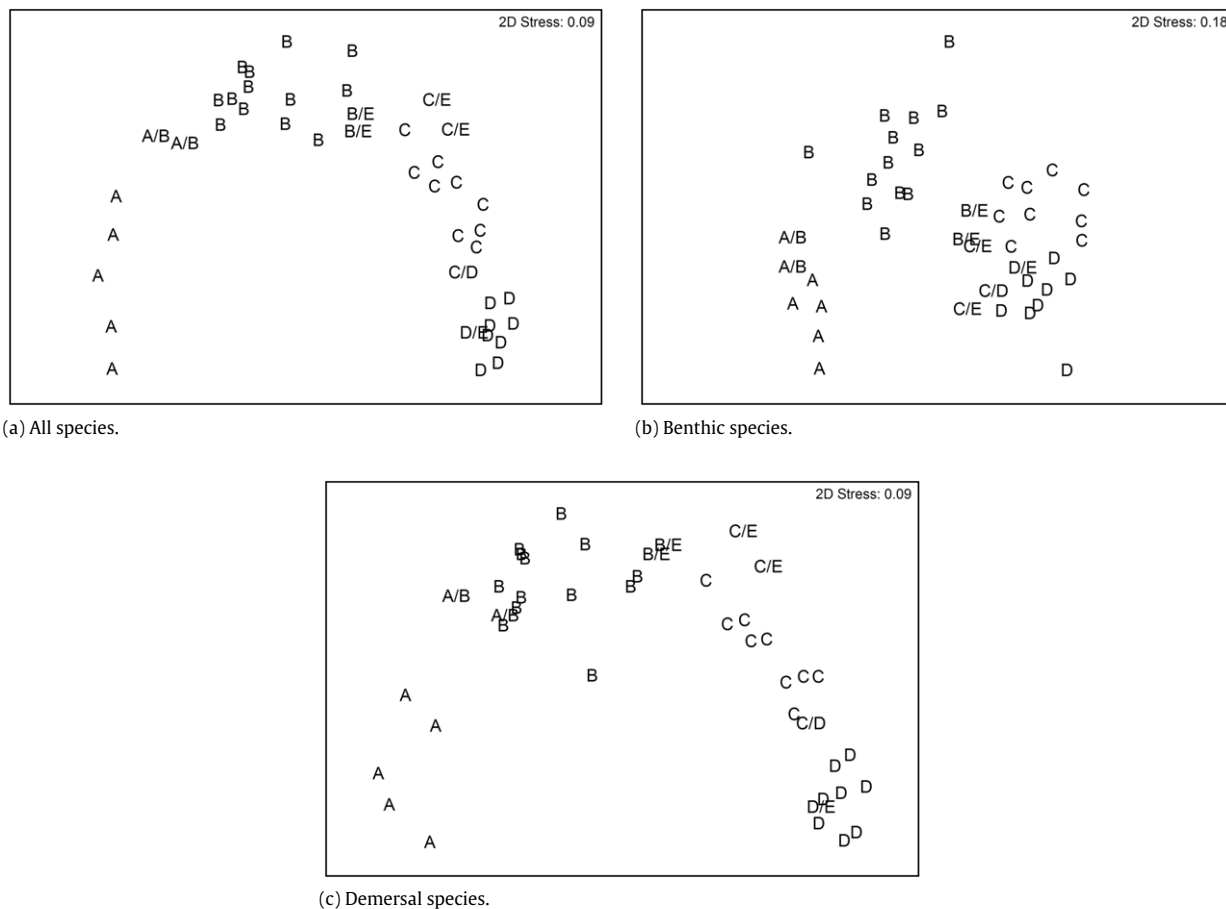
important characterising species for the deeper stations (cluster D) in this study.

In the case of benthic species, depth-related changes in assemblage structure were noted between the species groups down to a depth of ca. 200–300 m (distinguishing between group A stations, group B stations, and deeper stations) but differences between the deeper water stations comprising groups C, D and E were less marked. This may be due to species which are distributed independently of environmental gradients, which can confound the grouping of distinct communities. For instance cluster E had a wider depth distribution (231–602 m) overlapping with clusters C and D. In addition, the sea urchin *Cidaris cidaris* and the sea pen *Funicularia quadrangularis* were found in all five benthic groups. Although some typifying demersal species such as the deep-water

rose shrimp *Parapenaeus longirostris* and the European hake *Merluccius merluccius* were also found to have fairly eurybathic distributions, none of the demersal species occurred in all of the demersal groups. Similar patterns were observed by Colloca et al. (2003) (Tyrrhenian Sea) and Massutí and Reñones (2005) (Balearic Islands), who both found (1) a number of eurybathic demersal species with a wide depth distribution, and (2) several macroepibenthic species which were recurring over muddy bottoms on the continental slope, at depths greater than 200–300 m.

The benthic assemblages identified through the present study cannot be easily compared with those from other studies. For instance, neither Colloca et al. (2003) nor Massutí and Reñones (2005) undertook quantitative analysis for benthic species. Instead, these authors used the identity of benthic species to classify





**Fig. 4.** nMDS ordination plots for the stations based on a similarity matrix constructed using the Bray-Curtis index on square-root transformed abundance data for: (a) all species, (b) benthic species only, (c) demersal species only. Codes indicate the station groupings obtained through cluster analyses as shown in Fig. 3. Single-letter codes (A, B, C, D) represent stations which consistently grouped together in the same cluster. Stations which did not group within the same cluster in different analyses have multi-letter codes (e.g. A/B for stations M43 and M57, which were included in group A in the analysis based on benthic species and in group B in the analysis based on demersal species).

**Table 3**

Output of SIMPER analysis comparing the station groups resulting from cluster analyses (see Fig. 3) showing the mean similarity values of each group and mean dissimilarity values between groups. Separate results are shown for sub-sets of benthic and demersal species.

Group	Benthic species					Demersal species			
	A	B	C	D	E	A	B	C	D
Mean similarity	30.5	28.3	30.8	44.4	36.1	51.2	49.4	57.2	65.6
Mean dissimilarity									
A	–					–			
B	91.7	–				79.6	–		
C	97.3	90.6	–			94.8	77.2	–	
D	98.5	93.8	78.3	–		97.6	93.0	66.5	–
E	94.5	84.3	75.3	75.7	–	–	–	–	–

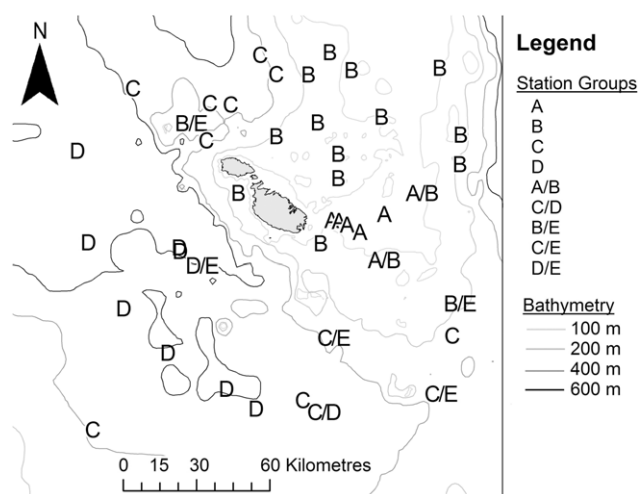
stations into pre-defined assemblage-types. However, the species characterising the epibenthic communities identified by these authors differ from the main benthic species contributing to similarity in the station groups identified in the present study. For example, only a few benthic species such as *Funicularia quadrangularis*, *Alcyonium palmatum*, *Parastichopus regalis*, and *Astropecten irregularis*, were identified in both the present study and in the northern Tyrrhenian Sea (Colloca et al., 2003), of which only *Astropecten* (no specific identity given) was also recorded from the Balearics (Massutí and Reñones, 2005). Several other species such as *Stylocidaris affinis*, *Cidaris cidaris*, *Trigloporus lastoviza*, *Centrostephanus longispinus* and *Scaurgus unicirrhus*, which were found to be common in the northern Sicilian Channel in the present

study, were not recorded by Colloca et al. (2003) or Massutí and Reñones (2005).

The only studies that undertook a quantitative analysis of deep-water mega-epibenthic species in the Mediterranean appear to be those by Ordines and Massutí (2009) and Mangano et al. (2013). Although Ordines and Massutí (2009) used the same approach as in the present study to characterise benthic assemblages, their sampling was limited to depths <255 m so their results are not directly comparable to ours. On the other hand, Mangano et al. (2013) determined the most important epibenthic characterising species in each of the five MEDITS depth strata, i.e. indicators were calculated for assemblages from *a priori* defined depth strata. The most important characterising species found on the outer shelf and shelf break (strata B & C) were *Astropecten irregularis*

**Table 4**  
Output of SIMPER analysis comparing the station groups resulting from cluster analyses (see Fig. 3) showing the main species contributing to similarity in each of the station groups. Only the top 15 species or those whose cumulative contribution is >90% are shown in each case. Av.D: mean density in the group (ind/km<sup>2</sup>); % Cont.: percentage contribution of species to within-group similarity. Separate results are shown for sub-sets of (a) benthic and (b) demersal species.

(a) Benthic species					
Group A			Group B		
Species	Av.D	% Cont.	Species	Av.D	% Cont.
<i>Stylocidaris affinis</i>	2978	25.42	<i>Funiculina quadrangularis</i>	98.8	21.13
<i>Cidaris cidaris</i>	2846	19.51	<i>Scaevurgus unicolorrhus</i>	35.8	19.91
<i>Trigloporus lastoviza</i>	588	11.95	<i>Cidaris cidaris</i>	39.2	9.51
<i>Centrostephanus longispinus</i>	1088	7.52	<i>Parastichopus regalis</i>	20.3	8.68
<i>Octopus vulgaris</i>	171	6.18	<i>Alcyonium palmatum</i>	8.5	7.29
<i>Hacelia attenuata</i>	1317	5.52	<i>Stylocidaris affinis</i>	39.9	5.26
<i>Pagurus alatus</i>	168	4.17	<i>Pennatula rubra</i>	9.5	5.11
<i>Cymodoce truncata</i>	160	3.58	<i>Galeodea echinophora</i>	53.9	4.98
<i>Pagurus carneus</i>	164	3.23	<i>Astropecten irregularis</i>	27.5	3.52
<i>Luidia ciliaris</i>	1029	2.50	<i>Lytocarpia myriophyllum</i>	4.3	2.92
<i>Funiculina quadrangularis</i>	703	1.48	<i>Homola barbata</i>	3.7	2.15
Group C			Group D		
Species	Av.D	% Cont.	Species	Av.D	% Cont.
<i>Nephrops norvegicus</i>	589	68.31	<i>Polycheles typhlops</i>	22.0	32.52
<i>Galeodea echinophora</i>	9.1	5.69	<i>Geryon longipes</i>	25.8	23.59
<i>Actinauge richardi</i>	3.7	4.81	<i>Nephrops norvegicus</i>	37.9	23.54
<i>Funiculina quadrangularis</i>	14.7	4.16	<i>Funiculina quadrangularis</i>	10.2	10.29
<i>Nemertesia sp.</i>	2.1	3.34	<i>Peltaster placenta</i>	6.4	5.05
<i>Scaevurgus unicolorrhus</i>	2.6	2.06			
<i>Cidaris cidaris</i>	4.8	1.95			
Group E					
Species	Av.D	% Cont.			
<i>Cidaris cidaris</i>	69.2	12.69			
<i>Nephrops norvegicus</i>	61.2	12.12			
<i>Scaevurgus unicolorrhus</i>	9.9	3.77			
<i>Actinauge richardi</i>	54.5	2.81			
<i>Funiculina quadrangularis</i>	5.7	1.29			
(b) Demersal species					
Group A			Group B		
Species	Av.D	% Cont.	Species	Av.D	% Cont.
<i>Serranus cabrilla</i>	2439	31.78	<i>Macroramphosus scolopax</i>	6693	15.86
<i>Mullus surmuletus</i>	1348	19.84	<i>Parapenaeus longirostris</i>	2044	9.35
<i>Serranus hepatus</i>	611	16.10	<i>Lepidotrigla cavillone</i>	1456	7.38
<i>Sepia officinalis</i>	148	8.76	<i>Merluccius merluccius</i>	807	7.13
<i>Sepia orbignyana</i>	117	6.20	<i>Capros aper</i>	1240	6.78
<i>Scyllorhinus canicula</i>	44.6	2.85	<i>Mullus barbatus</i>	663	6.76
<i>Mullus barbatus</i>	518	2.59	<i>Argentina sphyraena</i>	1117	4.72
<i>Boops boops</i>	116	2.27	<i>Citharus linguatula</i>	206	4.07
			<i>Serranus hepatus</i>	618	3.74
			<i>Lepidotrigla dieuzeidei</i>	522	3.54
			<i>Chelidonichthys cuculus</i>	228	3.29
			<i>Scyllorhinus canicula</i>	188	2.98
			<i>Boops boops</i>	251	2.66
			<i>Sepia orbignyana</i>	203	2.56
			<i>Illex coindetii</i>	85.9	1.99
Group C			Group D		
Species	Av.D	% Cont.	Species	Av.D	% Cont.
<i>Chlorophthalmus agassizi</i>	6440	28.9	<i>Aristaeomorpha foliacea</i>	848	28.33
<i>Parapenaeus longirostris</i>	4208	15.3	<i>Plesionika spp.</i>	816	22.93
<i>Plesionika spp.</i>	990	9.7	<i>Galeus melastomus</i>	750	15.58
<i>Merluccius merluccius</i>	431	6.8	<i>Etmopterus spinax</i>	134	8.97
<i>Galeus melastomus</i>	329	6.4	<i>Helicolenus dactylopterus</i>	67.1	5.66
<i>Helicolenus dactylopterus</i>	220	4.4	<i>Parapenaeus longirostris</i>	35.6	4.58
<i>Scyllorhinus canicula</i>	155	3.2	<i>Chlorophthalmus agassizi</i>	53.0	3.26
<i>Peristedion cataphractum</i>	177	3.1	<i>Merluccius merluccius</i>	20.5	2.67
<i>Pasiphaea spp.</i>	475	2.9			
<i>Todaropsis eblanae</i>	147	2.6			
<i>Aristaeomorpha foliacea</i>	153	2.2			
<i>Lepidorhombus boscii</i>	38.7	2.0			
<i>Lophius budegassa</i>	18.5	1.4			
<i>Dipturus oxyrinchus</i>	19.3	1.3			



**Fig. 5.** Bathymetric map of the GSA 15 area showing the geographical location of the sampled stations, with letter codes indicating station groupings obtained through cluster analyses as shown in Fig. 3. Single-letter codes (A, B, C, D) represent stations which consistently grouped together in the same cluster. Stations which did not group within the same cluster in different analyses have multi-letter codes (e.g. A/B for stations M43 and M57, which were included in group A in the analysis based on benthic species and in group B in the analysis based on demersal species).

and *Ophiura ophiura*; on the upper slope (stratum D) *Gracilechinus acutus* and *Astropecten irregularis*, and on the upper middle slope (stratum E) *Polychaetes typhlops* and *Geryon longipes*. Except for *Gracilechinus acutus* all these species were identified in the present study, and *Astropecten irregularis*, *Polychaetes typhlops* and *Geryon longipes* were also found to be the main species contributing to similarity in station groups, indicating similarity between benthic assemblages in the southern Tyrrhenian (Mangano et al., 2013) and northern Sicilian Channel (present study). However, only crustaceans, echinoderms and molluscs were analysed by Mangano et al. (2013), so no information on species belonging to other taxonomic groups is available.

Mangano et al. (2013) also assessed the effects of trawling disturbance on benthic communities. Areas subjected to high trawler fishing effort were found to have significantly lower abundance levels of structuring fauna such as crinoids and ophiuroids, and higher levels of mobile scavenging biota such as the starfish *Astropecten bispinosus*, the decapods *Medorippe lanata* and *Polychaetes typhlops*, and the portunid crabs *Liocarcinus depurator* and *Macropipus tuberculatus* (Mangano et al., 2013). Similarly, Smith et al. (2000) found higher densities of the echinoderms *Leptometra phalangium*, *Parastichopus regalis* and *Ophiura texturata* at untrawled sites. de Juan et al. (2007) noted a higher abundance of epifaunal scavengers and motile burrowing infauna at trawled sites, and a higher abundance of surface infauna and suspension feeders at unfished sites. Bottom otter trawling is a common fishing method in the Sicilian Channel, whereby otter doors and the ground rope are dragged over the sea bottom, impacting benthic and demersal communities. Therefore, trawl fishing may be an important factor influencing the structure of both benthic and demersal assemblages. The present study did not distinguish between trawled and untrawled areas, but a high diversity of epibenthic organisms including echinoderms was identified (Table 2). Structuring fauna such as, in particular, the sea pen *Funicularia quadrangularis*, were part of the main characterising species of all benthic station groups (groups A–E). In order to draw more definite conclusions on the impact of trawling on benthic species in GSA 15, detailed information on the spatial distribution of trawl fishing effort from Vessel Monitoring System (VMS) data would be required.

An interesting outcome of the present study is the strong correlation between benthic and demersal assemblages in terms

of variation in assemblage structure among stations (RELATE tests), leading to similar station groupings irrespective of whether the analysis was based on benthic species or demersal species. Only few previous studies have attempted to investigate the role of macro-epibenthic communities in structuring demersal assemblages (Colloca et al., 2003; Massutí and Reñones, 2005; Ordines and Massutí, 2009). These studies have shown a strong association between demersal assemblages and different pre-defined macro-epibenthic communities (Colloca et al., 2003; Massutí and Reñones, 2005) and a significant effect of habitat type on the distribution of demersal commercial species, with higher abundance of commercial species on maerl and *Leptometra phalangium* crinoid beds (Ordines and Massutí, 2009). *Leptometra phalangium* was found in shelf-break/upper slope habitats in the present study, but was not sufficiently abundant (average density of 2.2 ind/km<sup>2</sup>) to form the important crinoid beds recorded elsewhere in the Mediterranean (Colloca et al., 2004). Maerl habitats with a high diversity of associated species are present in GSA 15 (Lanfranco et al., 1999; Sciberras et al., 2009; Martin et al., 2014), and stations of the ‘A-group’ are all from an area known to have maerl and rhodolith beds. The most abundant structuring epibenthic species encountered in the present study which were characteristic of the assemblages identified (see Table 4) were the tall sea pen *Funicularia quadrangularis* (present at depths of ca. 50–700 m), the red sea pen *Pennatulula rubra* (ca. 100–450 m), the hydroids *Lytocarpia myriophyllum* (ca. 100–250 m) and *Nemertesia* sp. (ca. 100–600 m), the soft coral *Alcyonium palmatum* (ca. 100–400 m), and the anemone *Actinauge richardi* (ca. 100–600 m).

The present study provides information on the benthic assemblages found in the deep waters surrounding the Maltese Islands for the first time. It also appears to be the first Mediterranean study to have undertaken quantitative characterisation of both benthic and demersal assemblages down to 700 m depth in order to assess whether benthic and demersal assemblages have similar distribution patterns. However, it should only be considered a starting point for more detailed future investigations. The study used the best available data by collecting samples of non-target benthic species at MEDITS haul stations. Whilst the use of highly seasonal MEDITS trawl survey data from a restricted number of sampling stations for the characterisation of benthic communities has limitations, other techniques commonly used for studying deep-water benthic assemblages, such as ROV surveys, also yield essentially semi-quantitative data with a megafaunal bias. Overall the study objectives of (1) characterising the deep-water biocoenoses that occur in GSA 15, and (2) gaining an insight into whether deep sea benthic and demersal assemblages show the same patterns of distribution in GSA 15, were nevertheless achieved. This illustrates that despite such limitations, MEDITS data can indeed be ‘maximised’ and used to provide preliminary information in the absence of dedicated benthic mapping studies.

The general pattern of species groups characterised by their own particular assemblage structures in terms of both benthic and demersal species suggests that assemblages cannot be considered independently, and that interactions between benthic and demersal species are likely to be structuring forces for the demersal assemblages (Colloca et al., 2003). More detailed data from a larger number of sampling stations as well as information on fishing effort at the sampled stations is required in order to better understand such structuring forces in GSA 15. Nevertheless, the existence of well-defined assemblages shows that technical measures are required to protect these interdependent benthic and demersal communities; areas with distinct assemblages (as illustrated in Fig. 5) should be considered as separate management units (Dimech et al., 2008). Such considerations have direct implications for environmental monitoring and fisheries management in particular, since they highlight the need to move towards an ecosystem-based, multispecies approach to both assess and manage resources.

## Acknowledgements

We thank the various persons who contributed valuable expertise, namely Dr. Joseph A. Borg (University of Malta) for identifying crustaceans, Mr. Edwin Lanfranco and Dr. Sandro Lanfranco (University of Malta) for the identification of algae, Dr. Helmut Zibrowius (Centre d'Océanologie de Marseille, Marseille, France) for identifying anthozoans, Prof. Alfonso A. Ramos Esplá and Dr. Andrés Izquierdo (Universidad de Alicante, Spain) for identifying ascidians, Dr. Horia Galea (Hydrozoan Research Laboratory, Tourves, France) for the identification of hydroids, Dr. Alexander Ereskovsky and Prof. Jean Vacelet (Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale, Aix-Marseille Université, France) for identifying sponges, Dr. Gary Williams (California Academy of Sciences, San Francisco) and Dr. Dimitris Vafidis (University of Thessaly, Greece) for identification of pennatulaceans, Dr. M.A. Pancucci-Papadopoulou (Hellenic Centre for Marine Research, Greece) for identification of sipunculids and Dr. Paul D. Taylor (Natural History Museum, United Kingdom) for identification of bryozoans. An earlier version of this paper benefited from the constructive criticism of two anonymous reviewers, whom we thank.

This work is part of an ongoing collaboration between the Marine Ecology Research Group of the Department of Biology of the University of Malta and the Department of Fisheries and Aquaculture (DFA) within the Ministry for Sustainable Development, the Environment and Climate Change (MSDEC) of the Government of Malta.

This research was supported by funds from the University of Malta Research Committee (Project BENSPEFISH), for which we are grateful.

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