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Spatial Distribution and Temporal Variation of Megafauna in Circalittoral and Bathyal Soft Bottoms of the Westernmost Biodiversity Hotspot of the Mediterranean Sea: The Alboran Ridge

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Abstract: The Alboran Sea is the westernmost sub-basin of the Mediterranean Sea, and it is connected to the Atlantic Ocean through the Strait of Gibraltar. The Alboran Ridge is located in the middle of the Alboran Sea and represents a hotspot of biodiversity in the Mediterranean Sea. Besides their critical importance, there are few studies on the communities and changes in biodiversity, and they mostly concentrate on infralittoral and circalittoral bottoms. In this work, the composition, structure and bathymetric and temporal changes of megafauna of the Alboran Ridge were examined. Samples were collected from MEDITS surveys carried out between 2012 and 2022 at depths ranging from 100 to 800 m. Analyses were performed separately for each of the taxonomic groups: osteichthyes, chondrichthyes, crustaceans, molluscs, echinoderms and "other groups". There was no common spatial organization for each of the faunistic groups studied, although most of them displayed differences between the shelf and the slope. The continental shelf was characterized by the highest values of community metrics such as abundance, biomass, species richness and mean weight of species for all groups except for chondrichthyes and crustaceans. Decreasing trends of some community metrics were detected in some of the faunistic groups throughout the study period.

Keywords: bottom trawl survey; Alboran Sea; abundance; biomass; biodiversity

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1. Introduction

The Alboran Sea is the westernmost sub-basin of the Mediterranean Sea, and it is connected with the Atlantic Ocean through the Strait of Gibraltar. This sub-basin receives the surficial Atlantic water flowing through the Strait, while Mediterranean waters flow close to the bottom into the Atlantic Ocean. This phenomenon promotes singular oceanographic and hydrological conditions that support an exceptional marine biodiversity and a privileged transitional ecosystem between these two big basins [1–4], resulting in the confluence of organisms from different biogeographical areas (Lusitanian, Mauritanian and Mediterranean) in the Alboran Sea which has been frequently considered a biodiversity hotspot, a biogeographical sector and a self-standing ecoregion [5,6].

The Alboran Island, located in the middle of the Alboran Sea, is a small island of volcanic origin that is the emerged part of an underwater ridge that extends in a north–northeast direction. The privileged location of the Alboran Island and the adjacent platform, from a biogeographical point of view, has been previously highlighted, as it harbors some typical Mediterranean species, together with species of subtropical origin, from the African margin (North Africa and the Mauritanian region) and also from northwestern European margin (Atlantic–Lusitanian regions and even boreal regions) (see, [7–12]). Moreover, the Alboran Island and the Alboran Ridge harbor a wide variety of types of bottoms and habitats. For such reasons, among others, the Alboran Island (and its platform) is a hotspot of biodiversity within the Alboran Sea and may represent a key area for monitoring biodiversity changes in the Mediterranean Sea.

Despite their critical importance, there are few studies on communities and changes in biodiversity in this unique ecosystem of the Alboran Ridge. Some of the first research studies were carried out in the infralittoral and circalittoral bottoms. In 1985 and 1986, the benthic communities from bottoms exploited for red coral (*Corallium rubrum*) located between 75 and 130 m depth were characterized by Templado et al. [13]. This seminal study summarized general data and preliminary results regarding the fauna, while later, some reports were published focusing on particular taxonomic groups [14–16]. Fauna IV expedition (1996) included some sampling stations around the platform and slope of the Alboran Ridge using scuba diving techniques at 0–60 m depth and trawling techniques down to 450 m depth. A general monograph on the benthic fauna and flora surrounding the island was published in 2006 by Templado et al. [11]. One of the most recent research studies carried out around the Alboran Island down to 400 m was carried out by Gofas et al. [12] within the framework of the INDEMARES LIFE+ project. This latest study contributed to the declaration of a Site of Community Importance (SCI) in the platform of the Alboran Ridge known as "Espacio Marino de Alborán". Nowadays, there is still scarce knowledge of the biological communities from the deep areas of the Alboran Ridge.

The isolation of the ridge and the island from the Iberian and Moroccan continental margins and the fact that it is almost constantly subjected to strong currents result in very good water quality and in a good state of conservation of several habitats and benthic communities [3,10–12]. The relevance and specificity of the marine communities and resources of the seabed of the Alboran Ridge have determined the establishment of several types of Marine Protected Areas (MPAs) [4]. The first two MPAs surrounding the island, a Marine Reserve of 4.29 km^2 and a Fishing Reserve of about 490 km^2, were declared in 1997 by the Spanish Ministry of Agriculture, Fisheries and Food. The Fishing Reserve extends in outer waters up to 12 miles from the Alboran Island, excluding the Marine Reserve zones [11]. In 2001, the Alboran Island and its adjacent platform were included in the list of Specially Protected Areas of Mediterranean Importance (SPAMI) according to the Barcelona Convention. In 2003, the Andalusian Government declared the island and its platform (ca. 264.56 km^2) as a Natural Area (Paraje Natural), and the management plan for this and the associated SPAMI was approved in 2005. In 2003, the terrestrial section (ca. 0.8 km^2) was also declared as a Special Protected Area (SPA ES0000336). In 2006, an SCI (SCI ES6110015) coincident with the marine part of the Natural Area (ca. 263 km^2) was approved for the Alboran Island platform. In 2014, following the LIFE+ INDEMARES project, a new SCI proposal was adopted and named "Espacio Marino de Alborán".

One of the main anthropogenic activities in the Alboran Ridge is bottom trawling, which is only allowed in some areas of the Fishing Reserve and and it represents the most important fisheries targeting the deep-water species in Alboran Sea such as Aristeus antennatus (the blue and red shrimp). This crustacean species represents the most important resource of the bottom trawling carried out in the Alboran Ridge.This area corresponds to one of the Geographical Sub-Areas (GSAs) established by the General Fisheries Commission for the Mediterranean (GFCM) in 2009 (GSA 2: Alboran Island). Nevertheless, little is known about the communities occurring in the fishing grounds of the Alboran Ridge where the bottom trawling fleet operates, except for some general studies on molluscs [17,18], crustaceans [19] and echinoderm assemblages [20] of the Alboran Sea, which include some sampling stations in the Alboran Ridge. Therefore, research on the patterns of distribution and temporal variation of megafauna in the soft bottoms of the Alboran Ridge is crucial for improving the current knowledge of the biological communities of this ridge, the potential effects of these fisheries on the ecosystem, and for supporting future decisions about policies and strategies for the management and conservation of deep resources.

The aim of the present study is to analyze the composition and structure of megafauna caught during 10 surveys carried out in the soft bottoms of the shelf and slope of the Alboran Ridge. Moreover, the study aims to characterize bathymetric and temporal trends of the main faunistic groups. The study has used data from International Bottom Trawl Surveys in the Mediterranean (MEDITS), which provides annual information on demersal and epibenthic species of trawlable grounds of the northern part of the Alboran Sea, including the Alboran Ridge.

2. Materials and Methods

2.1. Data Collection

Biological data were compiled from a 10-year database of MEDITS surveys carried out along the Iberian Mediterranean coast by the Spanish Institute of Oceanography (I.E.O.). This specific work is based on those samples (hauls) taken on the Alboran Ridge (Figure 1) from 2012 to 2022 at depths between 100 and 800 m.

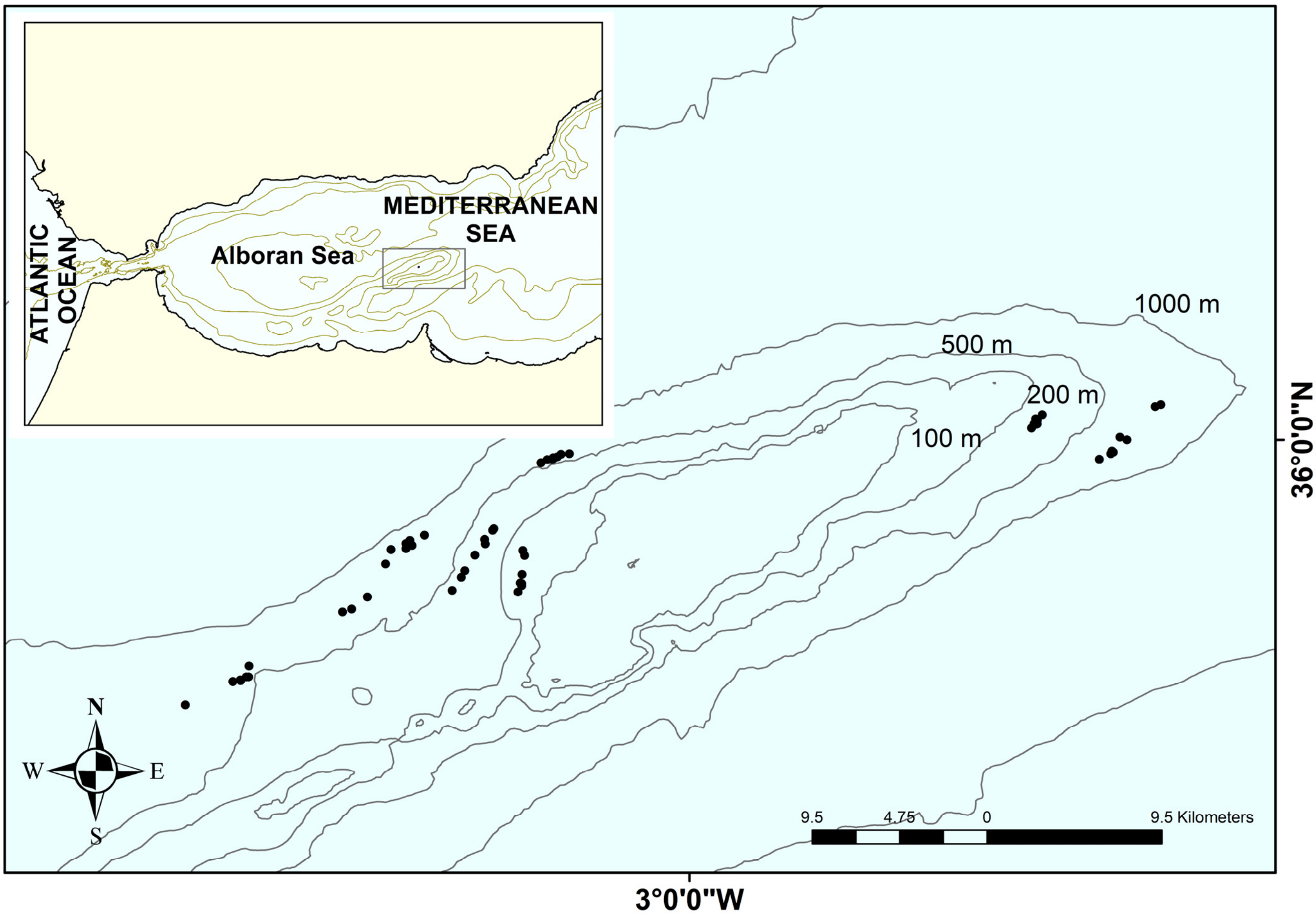

Figure 1. Map of the study area (Alboran Ridge) showing samples from the MEDITS survey from 2012 to 2022 (black points). Bottom trawling is not allowed at depths of less than 100 m depth and more than 1000 m depth (Ministerial Order, B.O.E. 233, ref. A-1998-22,628). No survey could be conducted in 2020 due to COVID-19 lockdown restrictions.

According to the MEDITS standardized protocol [21,22], the survey took place every year in spring. Sampling stations were chosen by applying a stratified random sampling scheme using depth as the stratification parameter. In the Alboran Ridge, the sampled bathymetric strata were 100–200 m (10 hauls), 201–500 m (20 hauls) and 501–800 m

(44 hauls), which correspond to Continental Shelf (CS), Upper Slope (US) and Middle Slope (MS), respectively. The duration of the hauls was fixed to 30 min for depths less than 200 m and 60 min for greater depths. The average swept area during each haul was 0.04958 km^2 for CS, 0.10208 km^2 for US and 0.11128 km^2 for MS. The sampling was carried out with a bottom trawl gear (GOC-73) designed for experimental purposes with a codend mesh size of 20 mm; the average vertical opening was 2.5 m, and the average horizontal opening was 18.5 m. For each sampling station, haul specimens were sorted, identified, counted and weighed on board.

For each species, the total number and weight (g) of the individuals were calculated. The frequency of occurrence of each species was calculated as the ratio between the number of occurrences of a species and the total number of hauls (hauls occurrence) or the number of years of occurrences of a species and the total of surveys years (years occurrence) (%). Pelagic species have been included in the analyses for considering the whole fauna inhabiting the study area, and their relevance in bottom trawl catches.

2.2. Statistical Analyses

For each haul, the number and weight of individuals per species were standardized to 1 km^2 in order to calculate both species abundance (number of individuals per km^2) and biomass (g per km^2). The mean individual weight was obtained for each species by dividing the biomass of the species by the number of individuals of that species. In order to identify bathymetric trends, multivariate analyses, such as cluster and nMDS, were carried out using abundance data. Previously, the data were log (x + 1) transformed in order to reduce the differences of the most dominant species. In each case, a resemblance matrix was obtained using the Bray–Curtis similarity index. SIMPER analysis was applied to reveal the contribution of each species to the similarity of the depth intervals (CS, US and MS). To study the temporal variation, the study period was divided into three time intervals—1, surveys from 2012 to 2015; 2, surveys from 2016 to 2018; 3, surveys from 2019 to 2022—in order to increase the number of observations and make the temporal analysis more robust. Two-way crossed ANOSIM analyses were applied to detect potential differences between the depth and time intervals. For each depth interval, the abundance (N), biomass (B), mean weight (M.W.), species richness (S) and Shannon–Wiener diversity index (H': log10) [23] were calculated. In order to test the significant differences among depth intervals and time intervals, a non-parametric analysis of variance (Kruskal–Wallis test) was carried out. Subsequently, the Local Polynomial Regression Fitting function (LOESS) was applied in those cases where the Kruskal–Wallis analysis resulted in significant temporal changes for better visualization of the long-term trends throughout the plotted time series. Analyses were performed separately by taxonomic groups, osteichthyes, chondrichthyes, crustaceans, molluscs, echinoderms and "other groups", which comprised all remaining taxa such as ascidians, thaliaceans, cnidarians, poriferans, brachiopods, annelids, sipunculans and algae. Those endangered, threatened and vulnerable species included in regional, national and/or international conservation lists (e.g., IUCN Red List, Berne Convection—Anex II, Barcelona Convention—Anex II or III, Habitat Directive or the Andalusian Red List of Invertebrates) were selected for further temporal analyses. From those, only the most frequent and abundant species were considered for studying the temporal changes of their abundance and biomass throughout the same time intervals (as described previously) using the Kruskal–Wallis analysis.

Scientific names assigned to all taxa followed the nomenclature of the World Register of Marine Species (WoRMS) [24].

3. Results

3.1. Biological Composition

A total of 329 taxa (including species and superior taxonomic groups) were identified during the ten MEDITS surveys. These were distributed in 13 diverse taxonomic groups: 99 taxa (30%) were osteichthyes, 62 (19%) molluscs, 59 (18%) crustaceans, 34 (10%)

echinoderms, 18 (5%) chondrichthyes and 57 (17%) "other groups". Of these 329 taxa, 124 (38%) were reported as occasional as they occurred in no more than 1 or 2 samples and 139 (42%) were only reported in 1 or 2 years. On the other hand, 65 species (20%) were constantly reported during the study period, with *Galeus melastomus* (chondrichthyes) as the most frequently occurring species (86.5%). Nineteen species are included in lists of species with some protection status (including endangered, threatened and vulnerable species) such as the IUCN Red List, Berne Convection (Anex II), Barcelona Convention (Anex II or III), Habitat Directive or the Andalusian Red List of Invertebrates. From those, 12 species occurred in no more than 1 or 2 samples, while another 12 occurred in no more than 1 or 2 years. The most frequent species was the gastropod *Ranella olearium*, detected in 21 samples (during 8 years of surveys), followed by the elasmobranch *Dalatias licha*, detected in 8 samples (during 7 years of surveys) (Table 1).

Table 1. Taxa (including species and superior taxonomic groups) detected in haul samples during MEDITS 2012-2022 in the Alboran Ridge. N: total abundance (individuals); W: total weight (g); F: frequency of occurrence (%); Min Depth and Max Depth: depth range of reported species (m). Nomenclature according to WoRMS [24]. (*) indicates those species included in lists of species with some protection status (endangered, threatened and vulnerable species).

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Osteichthyes						
Alepocephalus rostratus Risso, 1820	2468	354,018	35.1	100	545	800
Arctozenus risso (Bonaparte, 1840)	2	26	2.7	10	739	800
Argentina sphyraena Linnaeus, 1758	11	214	1.4	10	340	340
Argyropelecus hemigymnus Cocco, 1829	260	196	64.9	100	328	800
Arnoglossus imperialis (Rafinesque, 1810)	640	12,107	16.2	100	115	360
Arnoglossus laterna (Walbaum, 1792)	6	60	2.7	20	117	352
Arnoglossus thori Kyle, 1913	55	590	10.8	70	115	563
Bathysolea profundicola (Vaillant, 1888)	308	7434	27.0	100	328	545
Benthosema glaciale (Reinhardt, 1837)	353	329	27.0	70	332	800
Benthosema suborbitale (Gilbert, 1913)	11	9	1.4	10	751	751
Blennius ocellaris Linnaeus, 1758	10	130	8.1	60	117	136
Boops boops (Linnaeus, 1758)	1958	174,822	16.2	100	115	363
Callionymus maculatus Rafinesque, 1810	1	5	1.4	10	330	330
Capros aper (Linnaeus, 1758)	7361	74,426	47.3	100	115	686
Carapus acus (Brünnich, 1768)	2	10	2.7	20	117	130
Centracanthus cirrus Rafinesque, 1810	4021	215,323	12.2	90	115	154
Centrolophus niger (Gmelin, 1789)	2	3474	2.7	20	558	791
Cepola macrophthalma (Linnaeus, 1758)	1	66	1.4	10	127	127
Ceratoscopelus maderensis (Lowe, 1839)	48	56	21.6	80	332	800
Chauliodus sloani Bloch and Schneider, 1801	20	640	21.6	90	541	800
Chelidonichthys cuculus (Linnaeus, 1758)	117	13,602	12.2	90	115	154
Chelidonichthys lastoviza (Bonnaterre, 1788)	233	19,056	14.9	100	115	330
Chelidonichthys lucerna (Linnaeus, 1758)	1	2950	1.4	10	154	154

Table 1. *Cont.*

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Chlorophthalmus agassizi Bonaparte, 1840	1005	14,252	14.9	90	328	352
Coelorinchus caelorhincus (Risso, 1810)	85,251	776,586	52.7	100	136	793
Coelorinchus mediterraneus Iwamoto and Ungaro, 2002	3	113	2.7	20	793	800
Conger conger (Linnaeus, 1758)	252	63,211	70.3	100	328	800
Diaphus holti Tåning, 1918	3	6	2.7	20	739	793
Diaphus sp.	6	14	6.8	30	344	748
Epigonus denticulatus Dieuzeide, 1950	19,818	247,369	52.7	100	328	800
Epigonus telescopus (Risso, 1810)	22	11,814	14.9	90	551	800
Evermannella balbo (Risso, 1820)	3	20	4.1	30	554	695
Gadella maraldi (Risso, 1810)	1	2	1.4	10	556	556
Gadiculus argenteus Guichenot, 1850	92,970	517,419	35.1	100	117	764
Gaidropsarus biscayensis (Collett, 1890)	4	31	5.4	30	329	354
Glossanodon leioglossus (Valenciennes, 1848)	6375	100,310	4.1	20	117	351
Helicolenus dactylopterus (Delaroche, 1809)	3445	130,621	54.1	100	328	746
Hoplostethus mediterraneus Cuvier, 1829	11,109	67,764	78.4	100	328	800
Hygophum benoiti (Cocco, 1838)	30	24	6.8	30	541	746
Hygophum sp.	1	3	1.4	10	689	689
Hymenocephalus italicus Giglioli, 1884	1	10	1.4	10	329	329
Lampanyctus crocodilus (Risso, 1810)	3472	48,242	73.0	100	330	800
Lepidopus caudatus (Euphrasen, 1788)	41	876	14.9	60	115	526
Lepidorhombus boscii (Risso, 1810)	3	431	4.1	30	346	380
Lepidotrigla cavillone (Lacepède, 1801)	1	10	1.4	10	154	154
Lepidotrigla dieuzeidei Blanc and Hureau, 1973	1403	19,440	13.5	100	115	154
Lestidiops jayakari (Boulenger, 1889)	4	31	2.7	20	332	800
Lestidiops sphyrenoides (Risso, 1820)	2	19	2.7	10	351	793
Lobianchia dofleini (Zugmayer, 1911)	22	18	16.2	40	344	751
Lophius budegassa Spinola, 1807	83	139,641	52.7	100	115	800
Lophius piscatorius Linnaeus, 1758	10	72,492	12.2	50	117	735
Macroramphosus scolopax (Linnaeus, 1758)	24	116	6.8	40	115	332
Maurolicus muelleri (Gmelin, 1789)	2	4	2.7	20	330	339
Merluccius merluccius (Linnaeus, 1758)	19	4274	8.1	50	115	374
Microchirus variegatus (Donovan, 1808)	36	916	8.1	50	115	330
Micromesistius poutassou (Risso, 1827)	33	2959	17.6	60	328	742
Mullus surmuletus Linnaeus, 1758	3	298	4.1	30	128	154
Myctophidae Gill, 1893	3	5	2.7	20	554	751
Myctophum punctatum Rafinesque, 1810	15	27	14.9	70	115	642
Nemichthys scolopaceus Richardson, 1848	1	50	1.4	10	773	773
Nezumia aequalis (Günther, 1878)	11,679	293,135	62.2	100	332	800
Notacanthus bonaparte Risso, 1840	81	2713	28.4	90	545	800

Table 1. *Cont.*

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Notoscopelus bolini Nafpaktitis, 1975	1	4	1.4	10	739	739
Notoscopelus elongatus (Costa, 1844)	35	316	10.8	60	343	642
Ophichthus rufus (Rafinesque, 1810)	2	88	1.4	10	332	332
Ophidion barbatum Linnaeus, 1758	3	18	4.1	30	117	154
Ophisurus serpens (Linnaeus, 1758)	2	1260	2.7	20	332	340
Pagellus acarne (Risso, 1827)	1331	102,381	24.3	100	115	380
Pagellus bogaraveo (Brünnich, 1768)	53	8535	28.4	90	329	800
Pagellus erythrinus (Linnaeus, 1758)	3	235	2.7	20	128	136
Paralepis coregonoides Risso, 1820	5	38	4.1	10	328	558
Peristedion cataphractum (Linnaeus, 1758)	185	2572	16.2	70	330	374
Phycis blennoides (Brünnich, 1768)	900	134,402	82.4	100	328	800
Sardina pilchardus (Walbaum, 1792)	324	20,202	2.7	20	118	125
Sardinella aurita Valenciennes, 1847	2	292	1.4	10	117	117
Schedophilus medusophagus (Cocco, 1839)	7	5951	6.8	40	642	800
Scomber colias Gmelin, 1789	2	498	2.7	20	117	125
Scomber scombrus Linnaeus, 1758	1	239	1.4	10	117	117
Scorpaena elongata Cadenat, 1943	60	4873	20.3	100	115	380
Scorpaena loppei Cadenat, 1943	60	766	12.2	90	115	154
Serranus cabrilla (Linnaeus, 1758)	325	10,661	13.5	100	115	154
Serranus hepatus (Linnaeus, 1758)	550	6694	13.5	100	115	154
Sphoeroides pachygaster (Müller and Troschel, 1848)	1	119	1.4	10	130	130
Spicara smaris (Linnaeus, 1758)	1	46	1.4	10	118	118
Stomias boa (Risso, 1810)	170	1069	56.8	100	329	800
Symbolophorus veranyi (Moreau, 1888)	1	5	1.4	10	593	593
Symphurus ligulatus (Cocco, 1844)	3	16	1.4	10	751	751
Symphurus nigrescens Rafinesque, 1810	6	23	4.1	20	136	558
Synchiropus phaeton (Günther, 1861)	2181	41,666	40.5	100	136	800
Trachinus draco (Linnaeus, 1758)	13	1806	9.5	70	115	154
Trachurus mediterraneus (Steindachner, 1868)	43	1301	4.1	30	115	127
Trachurus picturatus (Bowdich, 1825)	117	10,712	9.5	70	115	564
Trachurus trachurus (Linnaeus, 1758)	8,075,908	4,063,083	35.1	100	115	695
Trachyrincus scabrus (Rafinesque, 1810)	4227	716,202	58.1	100	526	800
Trachyscorpia cristulata (Goode and Bean, 1896)	1	1950	1.4	10	746	746
Trigla lyra Linnaeus, 1758	4	487	4.1	30	329	351
Uranoscopus scaber Linnaeus, 1758	4	1072	5.4	40	117	130
Vinciguerria sp.	4	3	4.1	10	344	692
Zeus faber Linnaeus, 1758	8	11,453	6.8	50	117	154

Table 1. *Cont.*

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Chondrichthyes						
Centrophorus uyato (Rafinesque, 1810) (*)	2	4550	1.4	10	558	558
Chimaera monstrosa Linnaeus, 1758	97	40,101	44.6	100	380	800
Dalatias licha (Bonnaterre, 1788) (*)	9	22,012	10.8	70	526	793
Dipturus nidarosiensis (Storm, 1881)	24	8737.2	14.9	60	542	800
Dipturus oxyrinchus (Linnaeus, 1758)	4	9446	4.1	30	526	800
Dipturus sp.	1	1400	1.4	10	689	689
Etmopterus spinax (Linnaeus, 1758)	1947	196,400	64.9	100	329	800
Galeorhinus galeus (Linnaeus, 1758) (*)	1	9600	1.4	10	369	369
Galeus atlanticus (Vaillant, 1888)	5852	490,682	67.6	100	328	793
Galeus melastomus Rafinesque, 1810	23,450	2,701,574	86.5	100	328	800
Leucoraja circularis (Couch, 1838) (*)	2	68	2.7	20	346	752
Leucoraja melitensis (Clark, 1926) (*)	128	32,284	6.8	10	117	764
Leucoraja naevus (Müller and Henle, 1841)	417	173,595	35.1	90	115	751
Oxynotus centrina (Linnaeus, 1758) (*)	2	1149	2.7	20	380	800
Raja clavata Linnaeus, 1758	3	406	4.1	30	343	380
Scyliorhinus canicula (Linnaeus, 1758)	3593	439,875	47.3	100	115	582
Tetronarce nobiliana (Bonaparte, 1835)	10	46,583	10.8	40	332	791
Torpedo marmorata Risso, 1810	3	1415	4.1	20	346	363
Crustaceans						
Acanthephyra pelagica (Risso, 1816)	12	75	9.5	50	545	764
Aegaeon lacazei (Gourret, 1887)	4	6	5.4	30	360	569
Alpheus glaber (Olivi, 1792)	7	8	8.1	40	350	569
Amalopenaeus elegans Smith, 1882	2	2	1.4	10	558	558
Aristeus antennatus (Risso, 1816)	1702	37,902	39.2	100	545	800
Atelecyclus rotundatus (Olivi, 1792)	5	40	5.4	20	117	330
Bathynectes maravigna (Prestandrea, 1839)	184	6238	45.9	100	329	800
Calappa granulata (Linnaeus, 1758)	17	1551	1.4	10	329	329
Calocaris macandreae Bell, 1846	16	14	14.9	70	526	800
Chlorotocus crassicornis (A. Costa, 1871)	10	18	4.1	20	329	339
Dardanus arrosor (Herbst, 1796)	2602	11,857	68.9	100	115	800
Deosergestes henseni (Ortmann, 1893)	24	14	8.1	30	330	791
Dorhynchus thomsoni Thomson, 1873	10	7	6.8	30	354	771
Ebalia nux A. Milne-Edwards, 1883	1	1	1.4	10	564	564
Ergasticus clouei A. Milne-Edwards, 1882	34	45	16.2	60	330	642
Eurynome aspera (Pennant, 1777)	1	1	1.4	10	117	117
Eusergestes arcticus (Krøyer, 1855)	3	3	4.1	20	554	743
Geryon longipes A. Milne-Edwards, 1882	111	11,453	33.8	100	542	800
Inachus aguiarii de Brito Capello, 1876	1	1	1.4	10	136	136
Inachus dorsettensis (Pennant, 1777)	6	9	6.8	40	117	541
Inachus thoracicus Roux, 1830	2	2	1.4	10	125	125

Table 1. *Cont.*

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Iridonida speciosa (von Martens, 1878)	650	1526	5.4	30	332	352
Liocarcinus depurator (Linnaeus, 1758)	64	1233	13.5	70	117	374
Lophogaster typicus M. Sars, 1857	1	1	1.4	10	380	380
Macropipus tuberculatus (Roux, 1830)	452	8832	35.1	100	117	746
Macropodia tenuirostris (Leach, 1814)	34	56	17.6	90	115	692
Medorippe lanata (Linnaeus, 1767)	5	56	5.4	30	329	551
Monodaeus couchii (Couch, 1851)	32	149	31.1	100	117	800
Munida intermedia A. Milne-Edwards & Bouvier, 1899	26	315	12.2	60	329	360
Nephrops norvegicus (Linnaeus, 1758)	136	12,207.4	43.2	100	329	793
Pagurus alatus Fabricius, 1775	779	2871.4	59.5	100	344	800
Pagurus excavatus (Herbst, 1791)	1	7	1.4	10	330	330
Pagurus prideaux Leach, 1815	3084	23,791	44.6	100	115	791
Palinurus elephas (Fabricius, 1787) (*)	3	4536	4.1	30	117	136
Palinurus mauritanicus Gruvel, 1911	17	23,585	14.9	80	329	593
Parapenaeus longirostris (Lucas, 1846)	924	5961	21.6	100	329	551
Parthenopoides massena (Roux, 1830)	2	72	2.7	20	339	346
Pasiphaea multidentata Esmark, 1866	462	2972	55.4	100	526	800
Pasiphaea sivado (Risso, 1816)	1	1	1.4	10	329	329
Penaeopsis serrata Spence Bate, 1881	3	14	4.1	20	339	582
Philocheras echinulatus (M. Sars, 1862)	3	3	1.4	10	330	330
Phronima sedentaria (Forskål, 1775)	6	4	5.4	30	563	743
Plesionika acanthonotus (Smith, 1882)	1794	5131	58.1	100	526	800
Plesionika antigai Zariquiey Álvarez, 1955	1169	1951	21.6	90	328	752
Plesionika edwardsii (Brandt, 1851)	523	22,068	17.6	80	329	593
Plesionika gigliolii (Senna, 1902)	8	19	6.8	50	526	556
Plesionika heterocarpus (A. Costa, 1871)	11,806	29,111	24.3	100	328	566
Plesionika martia (A. Milne-Edwards, 1883)	4257	26,267	67.6	100	330	800
Plesionika narval (Fabricius, 1787)	1	1	1.4	10	330	330
Polybius henslowii Leach, 1820	1	4	1.4	10	136	136
Polycheles typhlops Heller, 1862	180	1368	48.6	100	332	800
Pontophilus spinosus (Leach, 1816)	2	3	2.7	20	330	563
Processa canaliculata Leach, 1815	12	30	10.8	50	329	569
Processa nouveli Al-Adhub and Williamson, 1975	2	1	1.4	10	330	330
Robustosergia robusta (Smith, 1882)	1841	3263	60.8	100	339	800
Scyramathia carpenteri (Thomson, 1873)	33	243	28.4	90	354	800
Solenocera membranacea (Risso, 1816)	48	116	23.0	100	329	593
Spinolambrus macrochelos (Herbst, 1790)	1	46	1.4	10	329	329
Squilla mantis (Linnaeus, 1758)	2	5	1.4	10	551	551

Table 1. *Cont.*

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Molluscs						
Abralia veranyi (Rüppell, 1844)	5240	13,708	50.0	100	115	800
Alloteuthis media (Linnaeus, 1758)	44	185	9.5	50	117	563
Alloteuthis sp.	11	73	1.4	10	127	127
Alloteuthis subulata (Lamarck, 1798)	28	143	5.4	30	115	564
Ancistrocheirus lesueurii (d'Orbigny, 1842)	1	354	1.4	10	548	548
Ancistroteuthis lichtensteinii (A. Férussac [in A. Férussac and d'Orbigny], 1835)	13	326	16.2	70	352	800
Aporrhais serresiana (Michaud, 1828)	30	89	16.2	60	329	771
Argonauta argo Linnaeus, 1758	1	5	1.4	10	593	593
Babelomurex benoiti (Tiberi, 1855) (*)	1	3	1.4	10	154	154
Baptodoris cinnabarina Bergh, 1884	1	1	1.4	10	566	566
Bathypolipus sp.	77	1239	16.2	50	330	800
Bathypolypus sponsalis (P. Fischer and H. Fischer, 1892)	154	5608	51.4	90	328	800
Berthellina edwardsii (Vayssière, 1897)	5	16	1.4	10	125	125
Brachioteuthis riisei (Steenstrup, 1882)	6	35	5.4	40	541	800
Buccinum humphreysianum Bennett, 1824	13	164	8.1	50	526	791
Calliostoma granulatum (Born, 1778)	2	4	2.7	20	350	360
Callumbonella suturalis (R. A. Philippi, 1836)	1	1	1.4	10	555	555
Capulus ungaricus (Linnaeus, 1758)	45	15	1.4	10	154	154
Chama circinata Monterosato, 1878	230	421	5.4	40	115	154
Chama gryphoides Linnaeus, 1758	5	16	1.4	10	125	125
Charonia lampas (Linnaeus, 1758) (*)	11	4395	9.5	70	117	136
Chiton sp.	30	30	1.4	10	154	154
Clelandella miliaris (Brocchi, 1814)	1	1	1.4	10	739	739
Colus jeffreysianus (P. Fischer, 1868)	8	54	4.1	10	542	739
Colus sp.	7	46	5.4	40	526	558
Cymbulia peronii Blainville, 1818	159	395	18.9	40	130	793
Eledone cirrhosa (Lamarck, 1798)	2	587	2.7	20	343	354
Eledone moschata (Lamarck, 1798)	119	24,739	17.6	100	115	354
Euspira fusca (Blainville, 1825)	13	56	9.5	60	330	747
Fusiturris similis (Bivona, 1838)	16	56	5.4	30	350	773
Galeodea rugosa (Linnaeus, 1771)	61	3660	33.8	100	526	800
Heteroteuthis dispar (Rüppell, 1844)	1	5	1.4	10	556	556
Histioteuthis bonnellii (A. Férussac, 1835)	5	2050	5.4	30	526	582
Histioteuthis reversa (A. E. Verrill, 1880)	12	365	13.5	50	541	752
Illex coindetii (Vérany, 1839)	320	38,042	16.2	60	117	764
Loligo forbesii Steenstrup, 1856	1332	109,041	32.4	100	115	380
Loligo vulgaris Lamarck, 1798	778	9048	2.7	20	125	127
Neopycnodonte cochlear (Poli, 1795)	4283	27,131	25.7	100	115	800

Table 1. *Cont.*

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Neorossia caroli (Joubin, 1902)	48	955	29.7	90	329	800
Octopus salutii Vérany, 1839	2	747	2.7	20	329	369
Octopus vulgaris Cuvier, 1797	168	66,470	14.9	100	115	360
Onychoteuthis banksii (Leach, 1817)	1	26	1.4	10	800	800
Orania fusulus (Brocchi, 1814)	9	9	1.4	10	130	130
Patellogastropoda	36	36	1.4	10	130	130
Peltodoris atromaculata Bergh, 1880	4	5	2.7	20	136	154
Pododesmus patelliformis (Linnaeus, 1761)	150	150	1.4	10	115	115
Pteria hirundo (Linnaeus, 1758)	5	20	1.4	10	115	115
Pteroctopus tetracirrhus (Delle Chiaje, 1830)	6	2496	4.1	30	328	351
Ranella olearium (Linnaeus, 1758) (*)	66	9189	28.4	80	117	800
Rhombosepion elegans (Blainville, 1827)	147	1173	16.2	90	115	343
Rhombosepion orbignyanum (Férussac, 1826)	7670	134,792	40.5	100	115	380
Rondeletiola minor (Naef, 1912)	141	171	13.5	90	328	380
Rossia macrosoma (Delle Chiaje, 1830)	279	7155	29.7	100	115	569
Scaeurgus unicirrhus (Delle Chiaje [in Férussac and d'Orbigny], 1841)	4	785	4.1	20	128	339
Scaphander lignarius (Linnaeus, 1758)	5	85	5.4	40	526	592
Semicassis saburon (Bruguière, 1792)	1	23	1.4	10	526	526
Sepietta oweniana (d'Orbigny, 1841)	122	247	10.8	50	330	374
Stoloteuthis leucoptera (A. E. Verrill, 1878)	1	1	1.4	10	346	346
Tetrarca tetragona (Poli, 1795)	3385	3507	13.5	90	115	360
Todarodes sagittatus (Lamarck, 1798)	319	96,137	78.4	100	115	800
Todaropsis eblanae (Ball, 1841)	9	899	9.5	50	332	380
Xenophora crispa (König, 1825)	647	6429	44.6	100	115	773
Echinoderms						
Anseropoda placenta (Pennant, 1777)	7	48	5.4	40	118	526
Antedon mediterranea (Lamarck, 1816)	1	1	1.4	10	735	735
Asterina gibbosa (Pennant, 1777) (*)	1	1	1.4	10	127	127
Astropecten irregularis (Pennant, 1777)	19	87	13.5	70	115	569
Centrostephanus longispinus (Philippi, 1845) (*)	2	89	2.7	20	117	125
Chaetaster longipes (Bruzelius, 1805)	85	661	31.1	100	115	739
Cidaris cidaris (Linnaeus, 1758)	179	4369	48.6	100	115	771
Coscinasterias tenuispina (Lamarck, 1816)	38	65	1.4	10	128	128
Echinaster (Echinaster) sepositus (Retzius, 1783)	1	70	1.4	10	130	130
Echinus melo Lamarck, 1816	117	30,227	31.1	100	115	800
Gracilechinus acutus (Lamarck, 1816)	269	3249	44.6	100	115	800
Hacelia attenuata Gray, 1840 (*)	1	11	1.4	10	128	128
Holothuria sp.	23	6123	21.6	70	154	800

Table 1. *Cont.*

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Hymenodiscus coronata (Sars, 1871)	554	18,229	18.9	90	136	771
Laetmogonidae Ekman, 1926	85	2063	13.5	30	332	742
Leptometra phalangium (Müller, 1841)	15	7	8.1	60	526	771
Luidia ciliaris (Philippi, 1837)	9	222	5.4	30	117	773
Luidia sarsii Düben and Koren in Düben, 1844	102	2504	32.4	100	330	791
Luidia sp.	3	42	4.1	30	344	742
Marthasterias glacialis (Linnaeus, 1758)	25	1352	6.8	40	115	800
Mesothuria intestinalis (Ascanius, 1805)	191	2946	18.9	40	380	800
Molpadia musculus Risso, 1826	5	18	2.7	20	566	695
Ophiocten abyssicolum (Forbes, 1843)	1	1	1.4	10	551	551
Ophioderma longicaudum (Bruzelius, 1805)	66	349	16.2	50	115	541
Ophiothrix fragilis (Abildgaard in O.F. Müller, 1789)	45	176	10.8	60	118	773
Ophiotrix sp.	20	41	4.1	20	115	360
Ophiura ophiura (Linnaeus, 1758)	16	82	9.5	30	130	751
Ophiura sp.	31	16	2.7	20	128	346
Parastichopus regalis (Cuvier, 1817)	334	74,429	54.1	100	115	800
Parastichopus tremulus (Gunnerus, 1767)	1	277	1.4	10	689	689
Sclerasterias sp.	1	11	1.4	10	125	125
Spatangus purpureus O.F. Müller, 1776	3	380	2.7	20	117	130
Stylocidaris affinis (Philippi, 1845)	1	210	1.4	10	354	354
Tethyaster subinermis (Philippi, 1837)	30	3651	29.7	100	125	800
Ascidians						
Ascidia mentula Müller, 1776	10	167	5.4	40	117	128
Ascidia sp.	3	9	1.4	10	593	593
Ascidiidae Herdman, 1882	22	184	2.7	20	118	130
Ciona intestinalis (Linnaeus, 1767)	11	263	2.7	10	328	558
Diazona violacea Savigny, 1816	20	3201	10.8	70	115	380
Microcosmus sp.	19	182	2.7	20	117	118
Polycarpa pomaria (Savigny, 1816)	1	7	1.4	10	127	127
Polycitor sp.	6	31	1.4	10	556	556
Pyura sp.	5	25	1.4	10	115	115
Thaliacea						
Pyrosoma atlanticum Péron, 1804	299	5810	52.7	90	115	800
Salpa maxima Forskål, 1775	119	3282	23.0	70	330	771
Salpa sp.	356	415	8.1	20	374	773
Cnidarians						
Actinauge richardi (Marion, 1906)	177	4233	39.2	90	343	800
Actiniidae Rafinesque, 1815	56	2302	5.4	10	329	791

Table 1. *Cont.*

Taxa	**N**	**W**	**F Hauls**	**F Years**	**Min. Depth**	**Max. Depth**
Alcyonium palmatum Pallas, 1766	9	51	6.8	40	117	363
Bebryce mollis Philippi, 1842	333	182	2.7	20	115	563
Caryophyllia smithii Stokes and Broderip, 1828	150	75	1.4	10	115	115
Cerianthus membranaceus (Gmelin, 1791)	3	209	2.7	10	374	563
Cerianthus sp.	1	17	1.4	10	330	330
Eunicella filiformis (Studer, 1878) (*)	133	72	6.8	50	117	564
Funiculina quadrangularis (Pallas, 1766)	39	251	13.5	70	330	582
Hormathia alba (Andres, 1881)	7	7	2.7	20	592	743
Isidella elongata (Esper, 1788)(*)	143	19	4.1	30	689	771
Kophobelemnon stelliferum (Müller, 1776)	39	212	8.1	40	555	771
Leptogorgia sarmentosa (Esper, 1791)	1	1	1.4	10	592	592
Lytocarpia myriophyllum (Linnaeus, 1758)	5	3	1.4	10	526	526
Nemertesia ramosa (Lamarck, 1816)	1	1	1.4	10	380	380
Paramuricea clavata (Risso, 1827) (*)	1	2	1.4	10	115	115
Pelagia noctiluca (Forsskål, 1775)	2287	46,142	35.1	60	118	793
Pennatula aculeata Danielssen, 1860	6	4	2.7	10	695	771
Pennatula phosphorea Linnaeus, 1758	3	13	4.1	30	115	558
Pennatula sp.	2	12	1.4	10	548	548
Spinimuricea atlantica (Johnson, 1862) (*)	1	3	1.4	10	563	563
Porifera						
Asconema setubalense Kent, 1870	7	3574	8.1	60	339	380
Axinella polypoides Schmidt, 1862 (*)	1	2	1.4	10	569	569
Phakellia ventilabrum (Linnaeus, 1767)	1	87	1.4	10	346	346
Poecillastra compressa (Bowerbank, 1866)	1	220	1.4	10	380	380
Porifera Grant, 1836	19	1265	16.2	70	117	566
Suberites domuncula (Olivi, 1792)	3	199	4.1	30	117	127
Thenea muricata (Bowerbank, 1858)	10	22	6.8	50	548	569
Brachiopoda						
Argyrotheca cuneata (Risso, 1826)	1	1	1.4	10	127	127
Megerlia sp.	2	1	1.4	10	127	127
Megerlia truncata (Linnaeus, 1767)	532	158	8.1	60	115	136
Novocrania anomala (Müller, 1776)	1	1	1.4	10	136	136
Terebratulina retusa (Linnaeus, 1758)	181	106	8.1	60	118	564
Terebratulina sp.	32	32	1.4	10	117	117
Annelida						
Aphrodita aculeata Linnaeus, 1758	49	210	21.6	80	117	771
Aphrodita sp.	1	4	1.4	10	582	582
Chloeia sp.	1	1	1.4	10	592	592
Chloeia venusta Quatrefages, 1866	1	1	1.4	10	695	695
Hyalinoecia tubicola (O.F. Müller, 1776)	1077	1109	13.5	70	117	564

Table 1. *Cont.*

Taxa	N	W	F Hauls	F Years	Min. Depth	Max. Depth
Laetmonice sp.	6	16	1.4	10	125	125
Polychaeta Grube, 1850	77	115	6.8	40	127	773
Pontobdella muricata (Linnaeus, 1758)	1	2	1.4	10	330	330
Spiochaetopterus sp.	145	121	5.4	30	125	771
Sipuncula						
Sipunculidae Rafinesque, 1814	15	76	5.4	40	551	752
Algae						
Laminaria ochroleuca Bachelot de la Pylaie, 1824 (*)	3	456	1.4	10	117	117

Cluster and nMDS results displayed some differences for each of the faunistic groups analyzed. Nevertheless, in almost all cases, a bathymetric trend of groupings of samples (interpreted as different assemblages) was detected (Figure 2). Regarding osteichthyes, two main groupings of samples were detected in relation to depth: one with samples from the shelf (CS; 100–200 m) and another one with those from the slope. In addition, two sub-groupings were identified in the slope, corresponding to upper slope (US; 201–500) and middle slope (MS; 501–800 m) samples. Regarding chondrichthyes, similar groupings with CS and slope samples were also detected. In the slope, two sub-groupings were also identified, which corresponded to US and MS samples but, in this case, displayed a lower similarity between them when compared to those of the osteichthyes. For crustaceans, two groupings were identified with CS and US in one grouping and MS samples in the other. In addition, two sub-groupings were also detected, one between 500 and 600 m depth and another one at depths larger than 600 m. Regarding molluscs, similar groupings of samples as those of crustaceans were detected, but no sub-groupings could be differentiated in the MS grouping. Regarding echinoderms, groupings of samples in relation to depth were less evident. Finally, no clear groupings of samples were detected for "other groups" (combining the data of remaining groups).

SIMPER analyses were carried out on each of the sample groupings (interpreted as different assemblages) for each depth interval (CS, US and MS). Table 2 shows those species characterizing each sample grouping by depth interval. For osteichthyes, the most representative species of these depth intervals were *Trachurus trachurus*, *Coelorinchus caelorhincus* and *Nezumia aequalis*, for CS, US and MS, respectively; for chondrichthyes, *Scylirohinus canicula* (CS) and *G. melastomus* (in both, US and MS); for crustaceans, *Pagurus prideaux*, *Macropipus tuberculatus* and *Plesionika martia*, for CS, US and MS respectively; for molluscs, *Neopycnodonte cochlear*, *Rhombosepion orbignyanum* and *Todarodes sagitattus*, for CS, US and MS respectively; for echinoderms, *Parastichopus regalis* (CS and MS) and *Gracilechinus acutus*; and for "other groups", *Megerlia truncata*, *Pyrosoma atlanticum* and *Actinauge richardi*, for CS, US and MS respectively. The average similarity values within the groupings of these depth intervals were highest for chondrichthyes (79.48%, 79.13% and 73.89% for US, CS and MS, respectively) and lowest for "other groups" (26.26%, 22.14% for CS and US, respectively) and echinoderms (19.13%, MS).

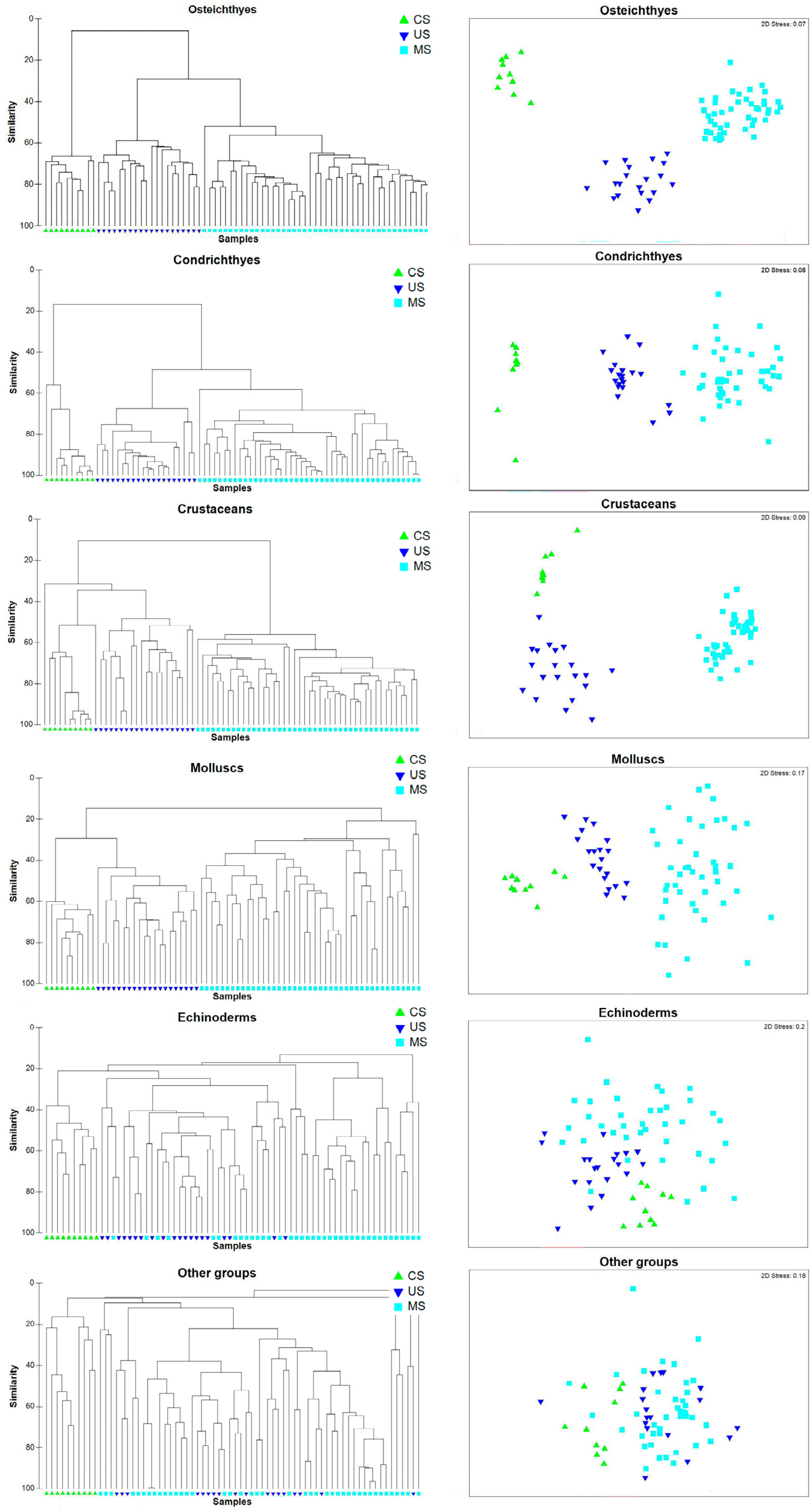

Figure 2. Results of cluster and nMDS analyses for each faunistic group carried out with abundance data (log (x + 1) transformed) from MEDITS 2012–2022. CS: 100–200 m depth; US: 201–500 m; MS: 501–800 m.

Table 2. Results of SIMPER analyses carried out with abundance data (log (x + 1) transformed) from MEDITS 2012–2022 regarding different faunistic groups and depth intervals. Cum%: cumulative % of species contribution. Cut off for low contributions: 50%. CS: 100–200 m depth; US: 201–500 m depth; MS: 501–800 m depth.

(a) Osteichthyes			**(d) Molluscs**		
CS—Average similarity: 70.68%			**CS—Average similarity: 66.28%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Trachurus trachurus	11.88	12.59	*Neopycnodonte cochlear*	8.69	17.08
Pagellus acarne	7.61	21.31	*Tetrarca tetragona*	7.38	29.61
Lepidotrigla dieuzeidei	7.66	29.88	*Xenophora crispa*	6.15	41.33
Boops boops	7.71	38.3	*Octopus vulgaris*	5.64	52.47
Serranus hepatus	6.81	45.97			
Arnoglossus imperialis	6.88	53.57			
US—Average similarity: 62.99%			**US—Average similarity: 54.38%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Coelorinchus caelorhincus	10.18	16.22	*Rhombosepion orbignyanum*	6.58	23.4
Gadiculus argenteus	9.69	30.88	*Todarodes sagittatus*	4.23	39.02
Capros aper	6.6	40.07	*Rossia macrosoma*	4.31	53.78
Synchiropus phaeton	6.19	49.12			
Helicolenus dactylopterus	5.24	56.19			
MS—Average similarity: 63.09%			**MS—Average similarity: 33.48%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Nezumia aequalis	7.54	19.28	*Todarodes sagittatus*	2.69	37.03
Hoplostethus mediterraneus	5.89	33.67	*Bathypolypus sponsalis*	2.11	58.28
Lampanyctus crocodilus	5.7	47.05			
Trachyrincus scabrus	5.46	58.95			
(b) Chondrichthyes			**(e) Echinoderms**		
CS—Average similarity: 79.48%			**CS—Average similarity: 50.91%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Scyliorhinus canicula	7.39	71.05	*Parastichopus regalis*	5.78	32.27
			Echinus melo	4.99	61.71
US—Average similarity: 79.13%			**US—Average similarity: 40.02%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Galeus melastomus	8.1	33.17	*Parastichopus regalis*	2.78	33.42
Scyliorhinus canicula	6.87	62.39	*Cidaris cidaris*	2.75	63.83
MS—Average similarity: 73.89%			**MS—Average similarity: 19.13%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Galeus melastomus	7.7	45.27	*Gracilechinus acutus*	2.01	27.6
Etmopterus spinax	5.67	77.8	*Cidaris cidaris*	1.25	43.61
			Luidia sarsi	1.43	58.28

Table 2. *Cont.*

(c) Crustaceans			**(f) Other groups**		
CS—Average similarity: 67.14%			**CS—Average similarity: 26.26%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Pagurus prideaux	6.91	50.07	*Megerlia truncata*	4.01	22.18
			Hyalinoecia tubicola	3.78	42.61
			Diazona violacea	2.7	60.54
US—Average similarity: 53.45%			**US—Average similarity: 22.14%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Macropipus tuberculatus	4.97	18.44	*Pyrosoma atlanticum*	2.64	46
Dardanus arrosor	5.15	36.45	*Pelagia noctiluca*	1.42	61.51
Pagurus prideaux	5.38	54.34			
MS—Average similarity: 63.79%			**MS—Average similarity: 24.01%**		
Species	**Av. Abund**	**Cum.%**	**Species**	**Av. Abund**	**Cum.%**
Plesionika martia	6.06	17.31	*Actinauge richardi*	2.21	41.38
Plesionika acanthonotus	5.52	33.61	*Pyrosoma atlanticum*	1.65	70.34
Sergia robusta	5.42	49.66			
Pagurus alatus	4.18	60.77			

The two-way crossed ANOSIM analyses between depth and time intervals (using abundance data) indicated high and significant differences among depth intervals across all time intervals for osteichthyes (R_{ANOSIM} = 0.978, $p \leq 0.01$), chondrichthyes (R_{ANOSIM} = 0.941, $p \leq 0.01$), crustaceans (R_{ANOSIM} = 0.992, $p \leq 0.01$) and molluscs (R_{ANOSIM} = 0.715, $p \leq 0.01$). These differences were also significant but less acute for echinoderms (R_{ANOSIM} = 0.347, $p \leq 0.01$) and "other groups" (R_{ANOSIM} = 0.40, $p \leq 0.01$). Regarding different time intervals (groupings of years of MEDITS surveys) across depth intervals, R_{ANOSIM} values were very low, generally <0.10 and not significant ($p > 0.01$), for osteichthyes, chondrichthyes and crustaceans, indicating no differences between the considered time intervals. Nevertheless, significant and a bit larger R_{ANOSIM} values were detected for molluscs (R_{ANOSIM} = 0.107, $p < 0.01$), echinoderms (R_{ANOSIM} = 0.183, $p < 0.01$) and "other groups" (R_{ANOSIM} = 0.150; $p \leq 0.01$). In general, R_{ANOSIM} values according to time interval comparisons were much lower than those detected in the depth interval comparisons. This indicates that the bathymetric variability is larger than the temporal variability of those intervals throughout the study period.

3.2. Community Metrics

Trends in community metrics regarding depth intervals were different for each faunistic group (Table 3; Figure 3). For abundance, maximum significant mean values were recorded on the CS assemblage in almost all faunistic groups, except for chondrichthyes that displayed maxima in the US assemblage. No significant differences between depth intervals were detected in the mean abundance of crustaceans. Regarding biomass, mean values for osteichthyes, molluscs, echinoderms and "other groups" showed significant decreasing trends with depth. In chondrichthyes, maximum mean values were recorded in the MS assemblage, whereas no significant differences were detected for crustacean biomass across depth intervals. Regarding mean weight, osteichthyes, molluscs and echinoderms showed significant maxima in CS, whereas chondrichthyes showed a significant increase with depth and "other groups" displayed maxima in the US assemblage. Crustaceans did not show significant differences between depth intervals. Species richness (S) showed significant maximum values in the CS assemblage for all taxonomic groups except for chondrichthyes and crustaceans, which showed an opposite trend with significant maxima in the US and MS assemblages. Finally, the Shannon–Wiener diversity index (H′) significantly increased with depth in osteichthyes and crustaceans but decreased with depth in echinoderms with maxima in CS. No significant differences of H′ were detected for molluscs and "other groups".

Table 3. Results of Kruskal–Wallis (H values) testing differences of abundance (N), biomass (B), mean weight (M.W.), species richness (S) and Shannon–Wiener index (H′) among depth intervals for each of the faunistic group analyzed. Data from MEDITS 2012–2022. ***: $p < 0.01$; **: $p < 0.05$.

	Osteichthyes	Chondrichthyes	Crustaceans	Molluscs	Echinoderms	Other Groups
N	51.8 ***	17.6 ***	5	54.1 ***	19.4 ***	21.7 ***
B	34.2 ***	8.5 **	0.2	55.1 ***	26.6 ***	11.7 ***
M.W.	12.5 **	7.5 **	2.6	19.7 ***	22.2 ***	10.2 ***
S	40 ***	27.8 ***	25.8 ***	42.4 ***	14.8 ***	17.4 ***
H′	16.0 ***	32.3 ***	26.1 ***	2.1	12.7 **	2.2

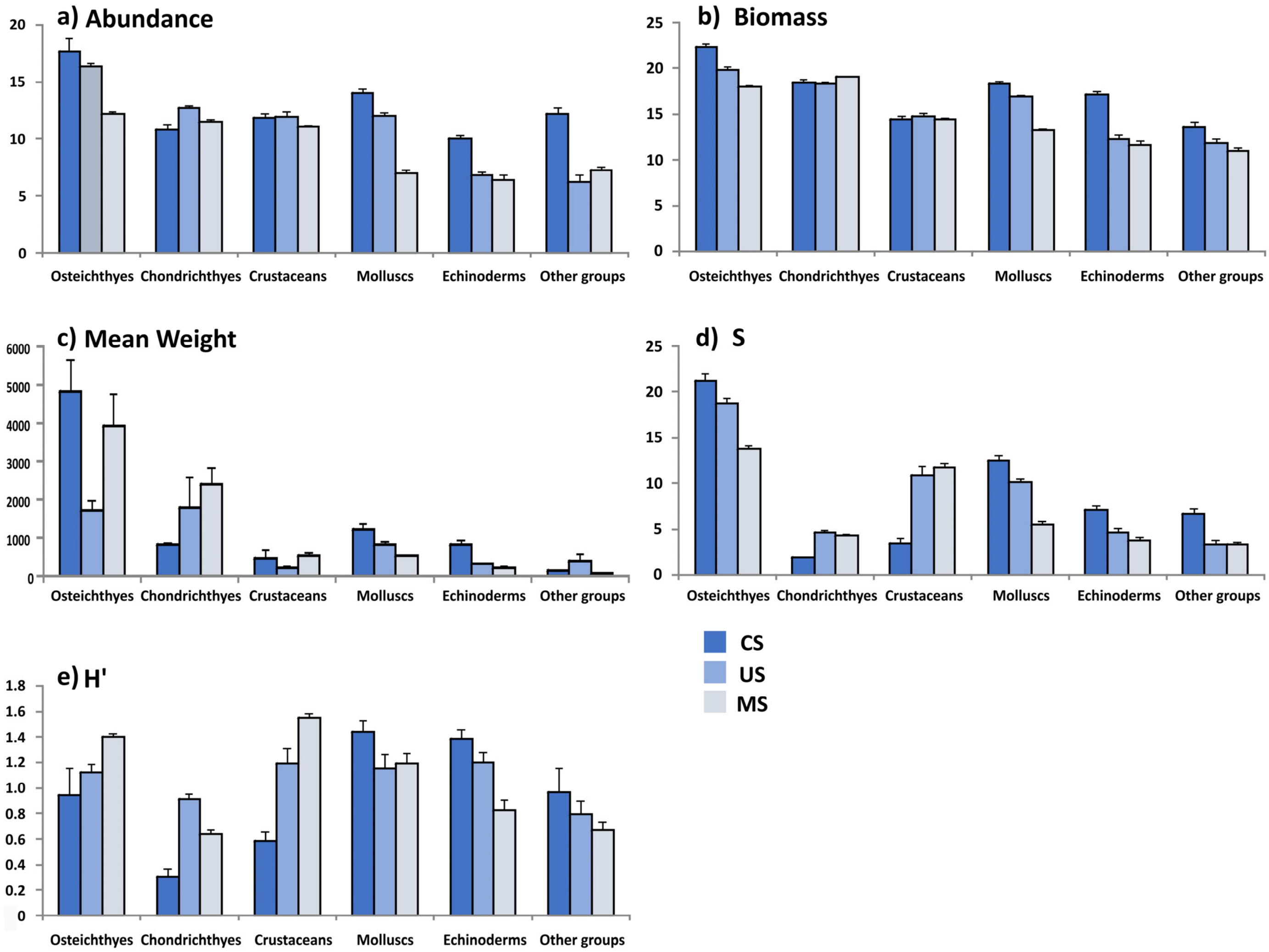

Figure 3. Mean values (± standard errors) of community metrics: (**a**) abundance (number of individuals/km^2) (log (x + 1) transformed); (**b**) biomass (g/km^2) (log (x + 1) transformed); (**c**) mean weight (g); (**d**) species richness (S); (**e**) Shannon–Wiener diversity index (H′). CS: 100–200 m depth; US: 201–500 m depth; MS: 501–800 m depth.

For analysis of temporal changes, the study period was differentiated into the same three year groups (time intervals) as in the multivariate analyses: 1 (surveys of 2012–2015), 2 (2016–2018) and 3 (2019–2022). Significant differences in the community metrics over these time intervals were tested using the Kruskal–Wallis analysis. (Table 4; Figure 4). Regarding abundance, significant temporal differences were detected for osteichthyes and chondrichthyes in the MS assemblages, both of them showing decreasing trends throughout the study period and for "other groups" in the US assemblage. Regarding biomass, a significant temporal decrease in the mean values was also detected for chondrichthyes and molluscs of the MS assemblages. Mean weight osteichthyes of the CS assemblage and molluscs of the US assemblage displayed significant differences throughout the study period. Regarding species richness, no significant temporal differences were detected for any of the faunistic groups and assemblages. Finally, for the Shannon–Wiener diversity index, significant temporal changes were only detected for osteichthyes of the US assemblage. Crustaceans and echinoderms did not display significant differences between time intervals in any of the community metrics. LOESS was applied in those cases where the Kruskal–Wallis analysis resulted in significant temporal changes for better visualization of the long-term trends throughout the time series plotted (Figure S1).

The temporal changes of the abundance and biomass of threatened, vulnerable and endangered species could only be studied in the most abundant and frequent species, such as the chondrichthyes *Dalatias licha* and *Leucoraja melitensis*, the crustacean *Palinurus elephas*, the molluscs *Charonia lampas* and *Ranella olearium* and the cnidarian *Eunicella filiformis*. Some decreasing trends were detected in the abundance and biomass of those species over the study period, however the Kruskal-Wallis analyses finally indicated no significant differences in any of those trends ($H < 3.3$, $p > 0.05$ in all cases).

Table 4. Results of Kruskal–Wallis (H values) testing differences of abundance (N), biomass (B), mean weight (M.W.), species richness (S) and Shannon–Wiener diversity index (H') between groups of years for each of the faunistic group analyzed. Data from MEDITS 2012–2022. ***: $p < 0.01$; **: $p < 0.05$.

CS (100–200 m)	Osteichthyes	Chondrichthyes	Crustaceans	Molluscs	Echinoderms	Other Groups
A	4	5.9	1.1	0.9	0.2	1.8
B	3.1	2.9	2.9	0.6	2.2	3.1
M.W.	6.7 **	2.9	5.1	0.5	3	0.1
S	3.1	1.5	3.5	0.3	0.4	1.2
H'	2.5	3.8	1.2	1.2	1.6	0.5
US (201–500 m)	**Osteichthyes**	**Chondrichthyes**	**Crustaceans**	**Molluscs**	**Echinoderms**	**Other Groups**
A	1.7	0.9	2.5	0.6	2.2	9.9 ***
B	0.9	5.9	0.3	2	3.3	4.7
M.W.	3.7	2.9	0.6	6.2 **	1.5	2.5
S	0.2	4.2	0.5	0.4	2.9	2.4
H'	10.3 ***	3.1	0.8	0.5	3.2	2.7
MS (501–800 m)	**Osteichthyes**	**Chondrichthyes**	**Crustaceans**	**Molluscs**	**Echinoderms**	**Other Groups**
A	8 ***	17.8 ***	0.1	5.5	1.3	0.8
B	5	17.0 ***	3.7	8.4 **	2.6	3.9
M.W.	1	5.7	4.8	5.5	1.8	1.5
S	1.8	0.6	0.7	2	0.7	0.7
H'	0.9	2.5	0.5	0.2	0.7	3.7

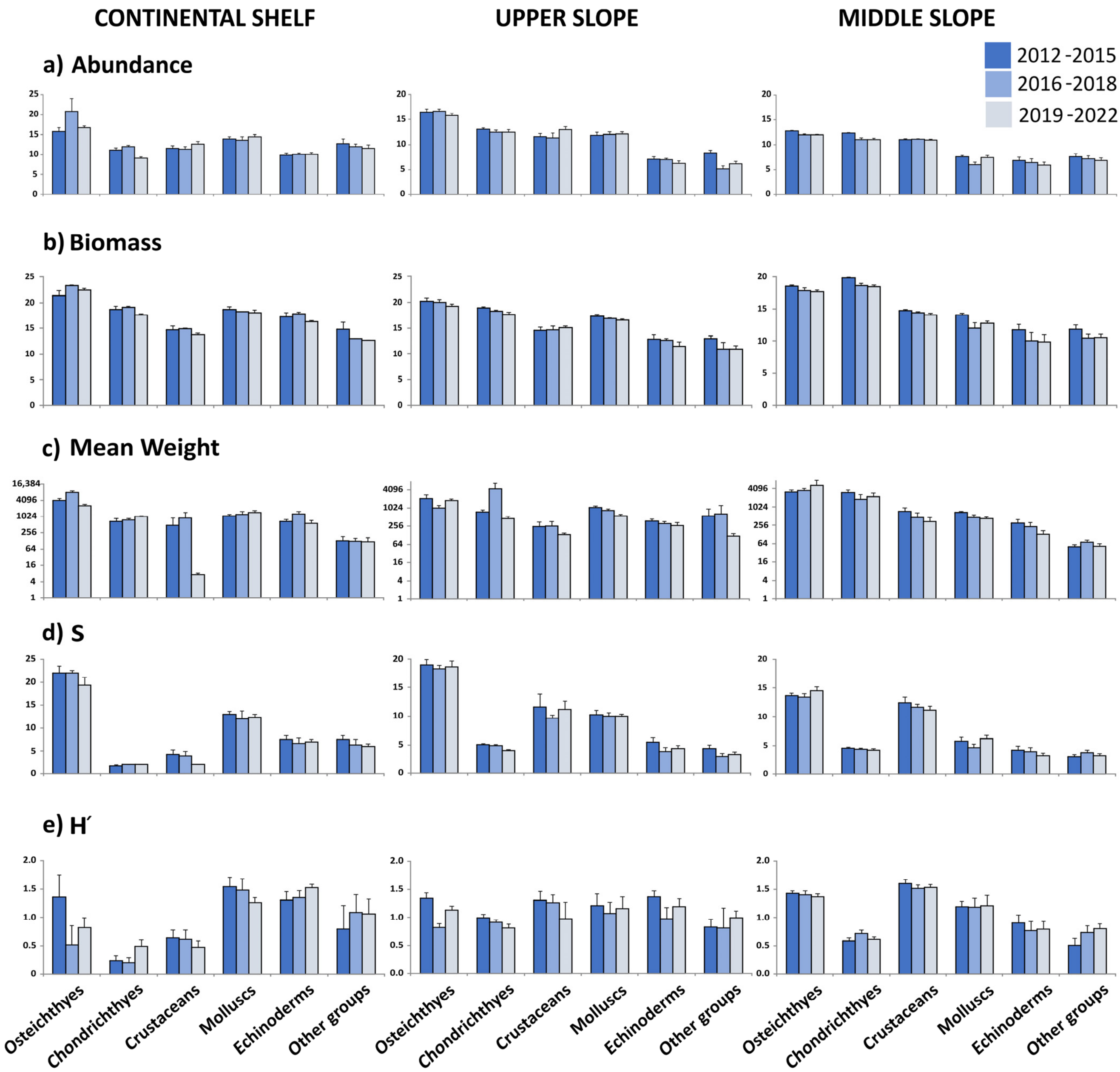

Figure 4. Mean values (±standard errors) of community metrics of different faunistic groups on CS (left panel), US (middle panel) and MS (right panel). (**a**) Abundance (number of individuals/km^2) (log (x + 1) transformed); (**b**) biomass (g/km^2) (log (x + 1) transformed); (**c**) mean weight (g) (logarithmic scale); (**d**) species richness (S); (**e**) Shannon–Wiener diversity index (H'). CS: 100–200 m depth; US: 201–500 m depth; MS: 501–800 m depth.

4. Discussion

In the present work, the composition, structure and bathymetric and temporal variability of benthic and demersal megafauna were examined on the continental shelf and upper and middle slope of the Alboran Ridge as part of the transitional ecosystem between the Mediterranean Sea and the Atlantic Ocean. The study provides detailed and novel quantitative information on some species and assemblages of circalittoral and bathyal soft bottoms around the Alboran Island. These were not generally considered in previous studies, which mainly focused on the intertidal, infralittoral and some circalittoral communities, such as coralligenous communities, rhodolith beds and bioclastic and gravel bottoms [11,12]. The present study reveals that a high number of species occur in those circalittoral and bathyal soft bottoms, which is consistent with the findings by previous authors for shallower areas around the island. Moreover, the present study has listed eight species (e.g., the bivalve *Chama gryphoides*, the annelid *Chloeia venusta*, the echinoderms *Coscinasterias tenuispina* and *Ophiocten abyssicolum*, among others) that were not previously included in the review of megabenthic invertebrates of Mediterranean trawlable soft bottoms made by Stamouli et al. [25] for the Alboran Sea. The high biodiversity detected in this and some previous studies consolidates the Alboran Ridge (where different Marine Protected Areas have been designated) as a biodiversity hotspot for the Alboran Sea and, therefore, for the whole Mediterranean Sea [4,12]. Previous works indicated that the insular shelf of the Alboran Ridge hosts more than a quarter (26.87%) of the total Mediterranean species richness of 11 benthic groups [2,12]. The high biodiversity detected on the Alboran Ridge is the result of its location and the complex environmental conditions (e.g., interaction of Atlantic and Mediterranean water masses, high diversity of bottom types and habitats), which promote a complex ecosystem with vulnerable marine ecosystems and protected/endangered species, contributing to its designation as both a Marine and a Fishing Reserve.

The Alboran Ridge is also a site included in the list of Specially Protected Areas of Mediterranean Importance (SPAMI) that harbor populations of threatened species, as it has been detected in the present study. Two vulnerable chondrichthyes species (*D. licha* and *Galeorhinus galeus*) and four critically endangered chondrichthyes species (*Centrophorus uyato*, *Leucoraja melitensis*, *L. circularis* and *Oxynotus centrina*), according to the International Union for Conservation of Nature (IUCN) [26], were reported in this study. In the Mediterranean Sea, chondrichthyes have shown a decline in species richness and abundance in recent decades [26–28], so monitoring of this group of fishes is particularly needed for an ecosystem-based approach [29]. In our study, chondrichthyes exhibited a high diversity compared to other areas of the Mediterranean surveyed with the same MEDITS protocol, such as the Tyrrhenian [30,31]. In contrast, insular areas generally have a higher diversity of chondrichthyes, such as those of Corsica, Sardinia and Sicily [32] as well as Malta [33,34]. Other threatened species reported in the present study are the lobster *Palinurus elephas*, a crustacean largely exploited due to its high commercial value with declining populations in the northern Alboran Sea [4] and the molluscs *Charonia lampas*, *R. olearium* and *Babelomurex benoiti*. The populations of the gastropod *C. lampas* are probably maintained in the Alboran Ridge thanks to their isolation from the Iberian and Moroccan continental margins, the absence of pollution [35] and the lower fishing pressure compared to the Iberian continental margin [17]. These *C. lampas* populations of the Alboran Ridge could be crucial for the conservation of this gastropod in the Alboran Sea since it is in serious decline along the Iberian continental margin. [36,37]. Other species detected in the Alboran Ridge and included in conservation lists are the echinoderms *Asterina gibbosa*, *Centrostephanus longispinus* and *Hacelia attenuata*; the sponge *Axinella polypoides*; and the cnidarians *Eunicella filiformis*, *Isidella elongata*, *Spinimuricea atlantica* and *Paramuricea clavata*. The latter gorgonian is not very common in the northern Alboran Sea, with a higher occurrence in the Strait of Gibraltar and the Alboran Ridge than in the northeastern sector of the Alboran Sea (except in Seco de los Olivos seamount – Chella bank) [37]. Finally, the algae *Laminaria ochroleuca*, which mostly occurs in cold and temperate areas of the NE Atlantic Ocean, can be found in the Alboran Ridge and in the Sicily channel. Nowadays, this species is considered a glacial relict in the Mediterranean, and its populations remain in localized areas with colder waters, such as those around the Alboran Island [38,39]. Some of the dominant species included in the conservation lists (e.g., *Dalatias licha*, *Leucoraja melitensis*, *Charonia lampas*, *Ranella olearium*, etc.) did not display any significant temporal changes in the Alboran Ridge, but some declining trends were detected throughout the study period. Further studies combining data obtained with other sampling methods (e.g., underwater images, beam-trawling, scuba-diving transects, etc.) and other areas and habitats of the Alboran Ridge should be carried out for better detection of potential declines in the populations of those species.

All faunistic groups, except echinoderms and "other groups", displayed a significant relationship with depth in the multivariate analyses, with a different bathymetric organization depending on the group. The faunistic segregation among CS, US and MS assemblages was similar to those previously reported for different faunistic groups in the western Mediterranean Sea (fish, [40]; chondrichthyes, [34]; crustaceans, [19,41]; molluscs (cephalopods), [42]; molluscs, [17]; megabenthic fauna, [43]). The segregation between shelf and slope is probably related to the response of organisms to wider changes in environmental variables and substrate types in the shelf when compared to the slope [17]. Further, down the slope, Carney [44] identified the 500 m depth (approximate boundary between the US and MS) as a zone of high species turnover mainly in response to biological factors such as food [45]. In addition, it should be noted that in the Mediterranean Sea, the water masses become more stable in terms of salinity and temperature below 150–200 m depth. Moreover, the slope bottoms are generally less heterogeneous, mainly composed of mud, and the light practically disappears [17,46].

Osteichthyes were very diverse in species, abundant and frequent in the samples, and it was the faunistic group with the clearest segregation of samples in relation to depth. These results are similar to other previous works on the structure of fish assemblages in the Mediterranean Sea [31,40,47], showing that fishes are strongly organized along a depth gradient due to their preference for specific environmental conditions [48]. However, in spite of the similarity of the assemblages from the Iberian continental margin [40] and the Alboran Ridge, some differences were identified in some of the most representative species. The fish *Capros aper*, for example, was very abundant in both areas (the continental margin and the Alboran Ridge) but displayed a deeper distribution in the Alboran Ridge as was previously reported for the Gulf of Vera [49]. This deeper distribution could be due to different environmental drivers because this is a species with limited swimming abilities that drifts with currents [50], so it could represent a potential indicator of the inflow of Atlantic water masses. Differences were also found in the abundance of *Lepidotrigla dieuzeidei*, which was one of the most abundant species in the CS of the Alboran Ridge with lower catches in the Iberian continental margin [51] and the Levante and Catalan coasts [52]. This is likely due to the type of bottom sediment of the Alboran Ridge platform, which is gravelly muddy sand of bioclastic origin, and this sediment type is more scarce in the continental margin [12,18]. The high dependence of this species upon the bottom sediment has also been reported in other studies with a density peak in specific sandy and gravelly bottoms [53].

Regarding crustaceans, two groupings were detected, one containing CS and US samples and the other one containing the MS samples. In addition, two sub-groups could also be differentiated: one between 500 and 600 m depth and another between 600 and 800 m. The depths of 500 and 650 m were also interpreted as faunal boundaries for decapod crustaceans by Cartes et al. [54] on the Cantabrian Sea and for all invertebrates in the western Mediterranean Sea [55]. Some of the most representative crustacean species of the present study also displayed differences in their bathymetric distribution in the Alboran Ridge when compared with the Iberian continental margin. For example, *Plesionika heterocarpus* and *Parapenaeus longirostris* displayed a deeper distribution in the bottoms around the Alboran Ridge than in the continental margin [19]. Both decapods also showed differences in their bathymetric distribution between the Gulf of Cádiz (Atlantic Ocean) and the northern Alboran Sea continental margin [56] or between the Algerian sub-basin and the Balearic sub-basin in the western Mediterranean Sea [57]. In the case of *P. heterocarpus*, those bathymetric differences were related to local environmental variables such as small-scale topographic features, bottom characteristics and local differences in primary production [57–59], as well as the different fishing pressure among the studied areas [60]. On the other hand, Colloca et al. [61] reported that the high sensitivity of *P. longirostris* to sea temperature variability, combined with its fast growth and high reproductive capability, makes this crustacean an indicator candidate species for detecting water temperature changes in the Mediterranean Sea.

Regarding molluscs, there were two main assemblages, one occurring in the CS and US and another one in the MS, being therefore similar to the bathymetric patterns reported by Ciércoles et al. [17]. Ciércoles et al. [17] and Moya-Urbano et al. [18] found that mollusc assemblages displayed geographical differences in composition and structure between the Alboran Ridge and the Iberian continental margin. Nevertheless, differences among those areas were less acute in the MS, probably due to higher environmental similarities between different areas in bathyal soft bottoms. The bivalves *N. cochlear* and *Tetrarca tetragona* were more abundant in the Alboran Ridge due to their habitat preference because these species generally inhabit bioclastic bottoms, and these types of bottoms are more common at 80–200 m depth on the Alboran Ridge platform than in the Iberian continental margin [12,17,18]. Another species with high catches in the present study, *Loligo forbesii*, also displayed differences between the continental margin and the Alboran Ridge, being more abundant in the latter [17]. This cephalopod occurs throughout the Mediterranean Sea but is scarce in the northwestern Mediterranean except in the Sicily Channel and northeastern Ionian Sea [62] as well as in the Balearic Islands [63]. These differences in the distribution of this species have been attributed to spatial surface temperature changes [62].

Groupings of samples related to depth were less clear for echinoderms and "other groups". The lack of acute changes in the composition and structure of those assemblages between the shelf and slope may indicate that several species, especially those with high abundances, are largely distributed independently of the environment [48]. Species such as *Parastichopus regalis*, which is the most abundant echinoderm species, showed a wide bathymetric range, from 115 to 800 m, suggesting that this holothuroid was poorly associated with depth. A wide bathymetric range was also detected for the echinoid *Cidaris cidaris* (115–771 m depth) and the asteroid *Tethyaster subinermis* (125–800 m depth). These echinoderms displayed a high contribution in shelf and slope samples, probably promoting similarities among them. It is worth mentioning the catch of the congeneric species *Parastichopus tremulus* during the 2022 survey in the Alboran Ridge. This is a species previously known only from the northeastern Atlantic Ocean until Ordines et al. [64] reported it for the first time in the Mediterranean Sea around the Seco de los Olivos seamount (Alboran Sea) in a scientific survey in 2017. This species has generally been collected in sedimentary habitats from the nearby Gulf of Cadiz from 500 to 800 m depth [64].

Regarding community metrics, the Alboran Ridge shelf was characterized by higher abundance and biomass in all groups except chondrichthyes and crustaceans. The reduction in abundance or biomass of osteichthyes and cephalopods with depth (with crustaceans and elasmobranchs displaying a different trend) was reported by other studies carried out in other Mediterranean areas [17,47,48,65]. According to Colloca et al. [48], the trend in osteichthyes and mollusc is partially related to the size–depth distribution of the dominant species, which perform ontogenetic migrations along the depth gradient. Higher mean weight values of osteichthyes and molluscs reported in CS could be partially related to the distribution of some shelf-dominant species, such as *Pagellus acarne* or *Octopus vulgaris*. Nevertheless, osteichthyes mean weight showed minimum values in the US that increased again in MS due to some dominant species, such as *Trachyrincus scabrus*. It seems that depth may influence the species richness in different ways. The number of species of nearly all taxa, except chondrichthyes and crustaceans, decreased with depth, while chondrichthyes increased significantly from the shelf to the middle slope. The latter increasing trend was previously detected for elasmobranches by Colloca et al. [48].

Neither chondrichthyes nor osteichthyes reported significant temporal changes, according to ANOSIM analyses. Nevertheless, in relation to community metrics, significant declining trends were detected in the abundance of both faunistic groups and the biomass of chondrichthyes in the MS assemblage. Regarding chondrichthyes, the differences in abundance and biomass values seemed to be due to the significant temporal decrease in catches of *G. melastomus* (Kruskal-Wallis analysis: $H = 28.8$, $p < 0.01$ and $H = 25.6$, $p < 0.01$, respectively) (Figure S2), which represents one of the most abundant species of the MS assemblage. Another chondrichthyan species, *E. spinax*, also very abundant in MS, showed a decreasing trend in catches (but it was not significant). In the osteichthyes group, decreasing trends (not significant) were reported for two species, *T. scabrus* and *N. aequalis.* It should be taken into account that the main activity carried out on the fishing grounds of Alboran Ridge is bottom trawling targeting demersal communities, with *Aristeus antennaus* being the most important resource between 500 and 800 m depth. The above-mentioned species constitute an important part of the discard; in fact, *G.melastomus* constitutes one of the most important species of the by-catch composition in Alboran Ridge [66], considering that the declining trends detected could be related to the fishing activity in recent years in the area. However, further studies are needed to contrast the trends of fishing pressure and important environmental factors on the populations of those species in the study area through the years.

5. Conclusions

The present study contributes to increas the knowledge of the fauna and assemblages occurring in the soft bottoms of the shelf and slope of the Alboran Ridge. The singularity of the Alboran Ridge ecosystem was highlighted due to differences in the composition and bathymetric distribution of assemblages and species in comparison to the Iberian continental margin. These differences may be related to the geographical location of the Alboran Ridge since it is considered to be a singular Atlantic–Mediterranean site due to the particular circulation of the surrounding water masses [7], its location (e.g., it is far from coastal activities and sewage or river discharge and lower fishing pressure) and some of its habitats that display a higher diversity and a healthier status than in other parts of the Alboran Sea [17]. There were no common bathymetric trends for each of the faunistic groups studied, although most of them displayed differences between the shelf and the slope. The shelf assemblage was characterized by higher values of community metrics such as abundance, biomass, species richness and mean weight of species for all groups except for chondrichthyes and crustaceans. On the middle slope, the abundance of osteichthyes and the abundance and biomass of chondrichthyes displayed significant decreasing trends throughout the study period. This seems to be related to decreasing trends of some of the most abundant species in that depth interval. However, more focused research on the effects of environmental factors and fishing efforts on the benthic and demersal megafauna will need to be performed in forthcoming studies. Finally, this study provides a baseline scenario for future analyses of Mediterranean biodiversity in European waters, such as the one carried out within the Marine Strategy Framework Directive (Directive 2008/56/EC).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d16110686/s1, Figure S1: Sample values of community metrics for year of survey for each faunistic group and depth interval; Figure S2: Sample values of abundance and biomass of *Galeus melastomus* for year of survey in the MS interval.

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Institutional Review Board Statement: For this study, real data were obtained in the framework of the MEDITS research surveys following a sampling scheme and standardized protocol approved by international authorities (EU/DG Mare, FAO/GFCM). If a live specimen of a rare species or a species subject to conservation measures was caught, it was quickly sampled and returned to the sea unharmed following the recommendation GFCM (http://www.gfcmonline.org/decisions/) on fisheries management measures for the conservation of sharks and rays in the GFCM area.

Data Availability Statement: Data sharing is not applicable to this article. In any case, access to the MEDITS database is formerly regulated by the EU Reg. 199/2008 (Data Collection Framework) and (EU) 2017/1004 (recast).

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Conflicts of Interest: The authors declare no conflict of interest.

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