Chapter 9
Decapod Assemblages in Mauritanian Waters

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Abstract We studied the decapods collected in four trawling surveys conducted in Mauritanian waters, in 281 hauls performed at depths between 81 and 1825 m, in November–December 2007–2010. A total of 214,982 specimens with a biomass of 1.6 tonnes was captured, Nematocarcinidae being the most abundant family, mainly due to one single species, *Nematocarcinus africanus*. *Parapenaeus longirostris* and *Glyphus marsupialis* were the species that most contributed to the total biomass, while *Acanthephyra pelagica* was the most common in the studied area. With a total of 118 species, belonging to 39 families, Mauritanian waters are more diverse in decapods than other comparable zones, probably due to the coexistence of tropical and temperate species. Two new species were described and some records increased the geographic range of certain species in the Atlantic. Five main assemblages were identified: shelf (< 100 m), deep shelf-upper slope (100–400 m), deep reef (400–550 m), middle slope (550–1400 m) and deep slope (1400–1800 m). Species of each assemblage are typified. Depth was the main factor structuring the assemblages, along with depth-dependant variables such as bottom temperature, longitude and organic matter content. Latitude also influenced assemblage structure. Greatest abundance and biomass occurred on the deep reef, in relation to minimum oxygen values (1.0–1.3 ml l^{-1}), which may favour the abundance of certain species, such as *N. africanus*, but negatively affect other

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species, resulting in a diversity reduction. Diversity generally increased with depth, the highest values being registered on the deep slope.

Introduction

The great productivity of Mauritanian waters has encouraged the presence of foreign industrial trawling fleets for more than fifty years (Sobrino and García 1992), as well as the recent development of a national trawl fleet (FAO 2006). While shrimp trawlers operate to 750 m (Sobrino and García 1992; García-Isarch, Spanish Institute of Oceanography, unpublished data, 2010), in recent years hake trawlers have operated in progressively deeper waters, reaching up to 1000 m depth (FAO 2006, Chap. 6). The trawling fishing pressure on Mauritanian bottoms is assumed to have an impact on the benthic environment, both directly, by removing target and non-target species (Jennings and Kaiser 1998; Philippart 1998; Kaiser 2000), and indirectly, as a result of the physical disturbance of the habitat structures (Jones 1992; Auster et al. 1996). To date, only the direct effects of the shrimper fleet on catch and discard species have been studied in Mauritanian fishing grounds (García-Isarch, Spanish Institute of Oceanography, unpublished data, 2011, 2012).

Macrobenthos composition is considered a good indicator of fishing pressure. Thus, changes in these communities are studied to evaluate the trawling effects on marine ecosystems. Decapods are amongst the dominant megabenthic taxa on the Atlantic continental shelf and slope, and the dominant group on the northwest African deep shelf and upper slope (Ramos, Spanish Institute of Oceanography, unpublished data, 2012). They are also a common component of deep benthic assemblages (Crosnier and Forest 1973). The importance of decapods in marine ecosystems also stems from their significant role in marine food webs, where they link high and low trophic levels (Cartes 1998), since they constitute an important food source for fish (Fanelli and Cartes 2010; Boudreau and Worm 2012; Torres 2013) and prey on a wide range of trophic levels (Fanelli et al. 2011a, b; Boudreau and Worm 2012; Torres et al. 2013). Thus, the diversity, wide distribution and ecological role of decapods make them an optimal target taxon for analyzing potential changes in the structure and dynamics of bathyal ecosystems (Cartes et al. 2007, 2014). The study of decapod communities in Mauritanian waters will therefore contribute to the analysis of potential changes in marine ecosystems attributed to anthropogenic activities (i.e., the trawling fishing impact on deep benthic communities) or linked to changes in climate and oceanographic conditions (see examples in Cartes et al. 2009a).

The state of the art of decapod knowledge in West Africa, recently reviewed by Muñoz et al. (2012), evidenced the general lack of specific studies about the ecology of decapods in Mauritanian waters. Assemblages of deep-sea decapods have been intensively studied in European waters, especially in the Mediterranean Sea and, to a lesser extent, in the North Atlantic (see examples referenced in Muñoz et al. 2012). Only a reduced number of studies on the decapod communities in West African waters included the analysis of deep-sea areas (Crosnier and Forest 1973; Macpherson 1991; Muñoz et al. 2012), and decapod assemblages in waters deeper than 1000 m are largely unknown.

In general, depth has been considered the main factor affecting the structure of deep-sea decapod communities (Abelló et al. 2002; Macpherson 1991; Cartes and Sardà 1993; Fariña et al. 1997; Company et al. 2004; Fanelli et al. 2007; Follesa et al. 2009; Papiol et al. 2012). Although environmental variables associated with depth (typically temperature and salinity) were not originally measured in deep-sea studies (Cartes and Sardá 1992; Maynou and Cartes 2000), recent analyses considered them as possible explanatory variables of the depth-related trends found (Cartes et al. 2007, 2014; Fanelli et al. 2013).

More recent research trends are focused on the study of decapods or other megabenthic communities in particular deep-sea marine habitats as submarine seamounts, canyons, hydrothermal vents and cold seeps or in special oceanographic environments as minimum oxygen zones (i.e.: Henrickx 2001; Cartes et al. 2007; Martin and Haney 2005; Ramírez-Llodra et al. 2010; Cartes et al. 2014). The studies on the oceanographic and geomorphologic features during the *Maurit* surveys resulted in the description of a number of complex habitats, defined both by their special geomorphology (submarine canyons systems, coral carbonate mounds barrier, seamount, etc.) and high productivity (see Chap. 17) that may have an impact on the decapods communities. The above mention cold-water deep sea coral reef constitutes a carbonate mounds habitat that extends along the slope at 400–550 m, from southern Cape Timiris to the Senegalese border (Chap. 13). Also a zone with minimum oxygen values (1.0–1.3 ml l^{-1}) was found at similar depths than the deep coral reef (300–550 m) (Chap. 3). These low oxygen values may affect decapod communities as dissolved oxygen concentration has been recognized as a major limiting factor for benthic and demersal species as respiration in most marine invertebrates may be affected at low oxygen concentrations (i.e. below 2.0 ml l^{-1}) (Rosenberg et al. 1991; Diaz and Rosenberg 1995).

This study contributes to the knowledge of the ecology of decapods on the Mauritanian continental shelf and slope, as part of the global benthic study undertaken in the area (see Chaps. 7 and 8). The aims of this work are to describe decapod fauna composition, and bathymetric and geographic distribution, to analyse their abundance and diversity, and to characterize the main assemblages and the environmental factors responsible for their distribution patterns.

Materials and Methods

Data Collection

Decapods were collected in four oceanographic surveys (*Maurit-1107*, *Maurit-0811*, *Maurit-0911* and *Maurit-1011*) of one month duration each, carried out between November and December of four consecutive years (from 2007 to 2010). The description of the survey methodology is detailed in Chaps. 1 and 4 (see Fig. 1.6 and Annexe 1.2 for station location and data). Briefly, the swept area method and a stratified sampling design was used, considering six bathymetric strata (80–200 m, 200–400 m, 400–800 m, 800–1200 m, 1200–1500 m and 1500–2000 m). A number of 291 fishing hauls were performed with a commercial Lofoten bottom trawl with 17.70 and 5.5 m of respective horizontal and vertical openings and 35 mm mesh size at the codend. Trawls were performed at an average speed of 3.1 knots. Decapods collected at each trawl were sorted and initially identified on-board to the lowest taxonomic level, then counted and weighed. A representative collection of all species was preserved in 70% ethanol for further study in the laboratory, where they were thoroughly examined.

Data Analysis

For each species, abundance (in number of individuals) and weight (in kg) per haul were recorded. These values were standardized to the swept area of each trawl to obtain abundance and biomass per a surface unit of 0.1 km^2. Data matrices of numerical abundance and weight by species and station (number and kg per 0.1 km^2) (see details in Chaps. 1 and 4) were prepared.

In order to evaluate the completeness of the sampling (thus, if the number of sampling stations is enough to describe the decapod community), the observed species richness was compared with predicted species richness estimated using a number of statistical estimators (ACE, ICE, Chao 1, Chao 2, Jackknife 1, Jackknife 2, Bootstrap and Michaelis-Menten means) calculated with the software program EstimateS (Version 9.1.0) (Colwell 2013). The overall inventory completeness (the percentage of species that is not singletons) and the mean value of completeness (the percentages of species observed in relation to each estimator) were calculated. The patterns of the species accumulation curves obtained from our observed data and from those of the eight estimators were visually analysed to search if an asymptote was reached, this indicating a complete sampling. Ecological indicators, such as abundance (N), biomass (B), occurrence (F, frequency of appearance of the species in the hauls), species richness (S) and the Shannon-Wiener diversity index (H′), were estimated for each station. Total decapod abundance, biomass and diversity were spatially represented by geostatistical techniques. For that, ArcGIS

krigging with a spherical semivariogram, with 12 neighbours, and the output cell size of 1000 m was used.

The main species were ranked in total abundance (N) and total biomass (kg). For each species, we also determined the bathymetric and latitudinal ranges in the zone studied.

To identify the species assemblages we applied clustering and non-metric multidimensional scaling (MDS) analysis to the similarity matrix obtained after performing a 4th root data transformation of species abundance (N) by station. Similarity levels between hauls were calculated by means of the Bray-Curtis index (Clifford and Stephenson 1975). Species appearing in both low frequency (<4% of the hauls) and low abundance (<0.07% of N) were removed, as well as hauls where only one species was collected, in order to reduce the proportion of zeros in the matrix. A two-way crossed analysis of similarities (ANOSIM) was performed to test for statistically significant differences in the decapod assemblage structure between samples. The similarity percentages SIMPER procedure was used to characterize the species assemblage by calculating the contribution of each species to the similarity (typical species) and to the dissimilarity (discriminating species) between groups of samples belonging to the same depth stratum (Clarke and Warwick 2001). The above-mentioned ecological indicators were also calculated for the assemblages identified. Within each decapod assemblage, we ranked the main species in abundance, biomass and occurrence.

Environmental Variables

Depth, latitude and longitude were registered in all the performed hauls. Bottom temperature was recorded in 189 hauls by a net sensor SBE 37-SM Micro CAT. Sediments samples were taken during trawling in a number of 60 stations, using a 9 cm diameter and 40 cm length steel tube fixed to the lower part of the net mouth. Sediment variables (organic matter, carbonate content and grain size composition) were analyzed for these 60 stations (see detailed sampling description in Chap. 2).

To assess the influence of these environmental and geographical variables potentially affecting the distribution patterns of the decapod assemblages, we analysed their relationships through the BEST routine, by applying the BIOENV method and estimating the Spearman's rank correlations. A draftsman's plot was previously performed on the environmental and geographical data to search for autocorrelation among the potential variables identified, considering that variables were auto correlated when the Pearson's correlation (ρ) was higher than 0.7.

All analyses were computed with the software package PRIMER vs. 6 (Clarke and Warwick 2001).

Results

Global Overview

A total of 118 decapod species, belonging to 39 families, were identified at depths ranging from 81 to 1825 m on the Mauritanian shelf and continental slope. The overall inventory completeness was 82% and the mean value of percentage completeness from the eight estimators was 87% (Table 9.1). These percentages,

Table 9.1 Summary table of decapods sample and species richness estimates

No. Samples	281
Observed Richness (S)	118
No. Singletons	21
% Inventory Completeness	**82**
No. Doubletons	8
Richness estimates	
ACE	138
ICE	140
Chao 1	146
Chao 2	135
Jack 1	142
Jack 2	149
Bootstrap	130
MMMeans	115
% Completeness	
ACE	86
ICE	84
Chao 1	81
Chao 2	87
Jack 1	83
Jack 2	79
Bootstrap	91
MMMeans	103
Mean % Completeness	**87**

The results of the indicators of sampling efficiency are highlighted in bold
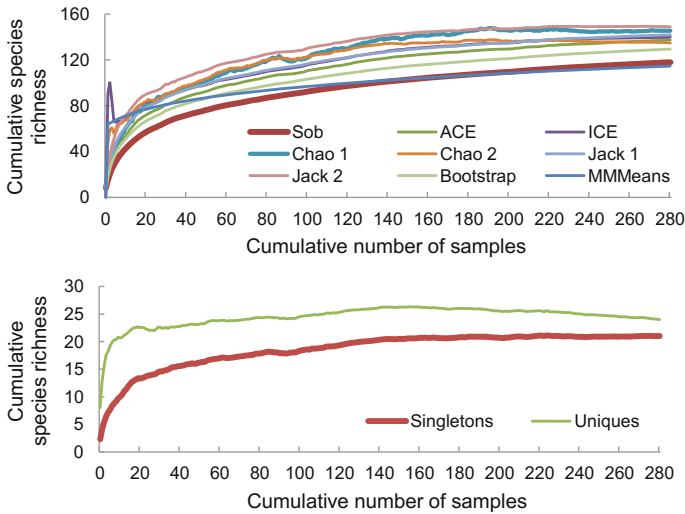
Fig. 9.1 *Top* Species accumulation curves of the observed species (Sob) and estimated species richness. The estimators used are ACE, ICE, Chao 1, Jackknife 1 (Jack 1), Jackknife 2 (Jack 2), Bootstrap and Michaelis-Menten Mean (MMMean) and were generated by EstimateS (Version 9.1.0) (Colwell 2013). *Bottom* Species accumulation curves of singletons and doubletons
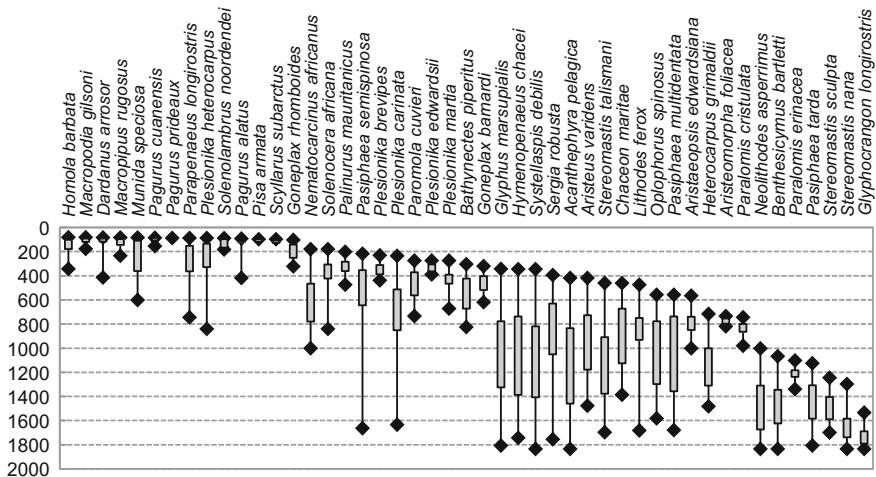

Fig. 9.2 Bathymetric and interquartile range of the 47 most representative decapod species inhabiting the Mauritanian deep shelf and continental slope

together with the fact that asymptote was reached in most the estimators accumulation curves (Fig. 9.1), showed a high sampling efficiency, demonstrating that the sampling method yielded a high percentage of the present species.

Annexe 9.1 shows the decapod taxonomic list, together with the bathymetric and latitudinal ranges, habitat (benthic, nectobenthic or pelagic) and the main biotic variables for each species. Figure 9.2 shows the bathymetric ranges of the main decapod species.

The most diversified group was the infraorder Caridea, represented by 40 species. The families with the highest species richness were Oplophoridae (12 species) and Pandalidae (11 species), followed by Inachidae (8 species), Pasiphaeidae (7 species) and Lithodidae, Penaeidae, Sergestidae and Crangonidae (5 species each) (Fig. 9.3). The other families were less diversified.

A total of 214,982 individuals reaching a biomass of 1.6 t were captured in the four *Maurit* surveys. Mean values of N and B were 793 individuals *per* 0.1 km^2 and 56 kg *per* 0.1 km^2, respectively. Caridea and Dendobranchiata were the most important groups, contributing to the 51 and 31% of the total abundance and to the 40 and 30% of the biomass. Other important groups were Anomura (12% of abundance and 15% of biomass) and Brachyura (4 and 9% of abundance and biomass, respectively). Nematocarcinidae were the most abundant family (37% of the total abundance), mainly due to one single species, the African spider shrimp *Nematocarcinus africanus*. Together with Penaeidae (19%), this family accounted for more than half of the total abundance. The remaining families were present with abundances lower than 10% (Fig. 9.4). In terms of biomass, Pasiphaeidae (22%), Penaeidae (19%), Nematocarcinidae (17%) and Lithodidae (13%) were the most important families.

The highest decapod abundances were found between Nouakchott and the Senegalese border, continuously distributed between 200 and 1000 m depth (Fig. 9.5). In northern Nouakchott, the highest abundance values were patchily distributed, peaking at southern Cape Blanc and off the Arguin Bank, and northern and southern Cape Timiris. Biomass followed a similar pattern in the northern area,
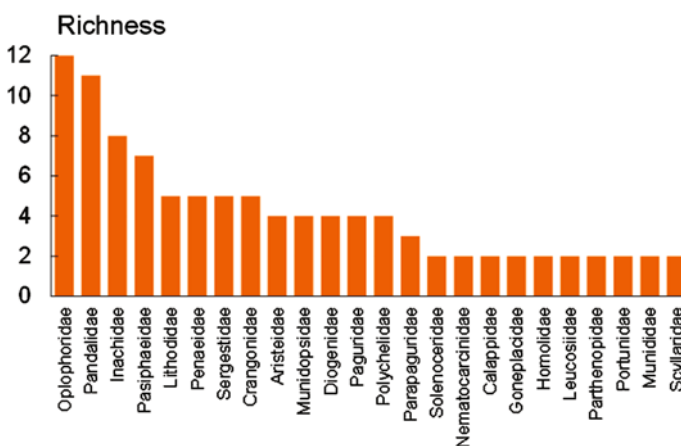

Fig. 9.3 Specific richness for the 24 main families of decapods in Mauritanian deep waters
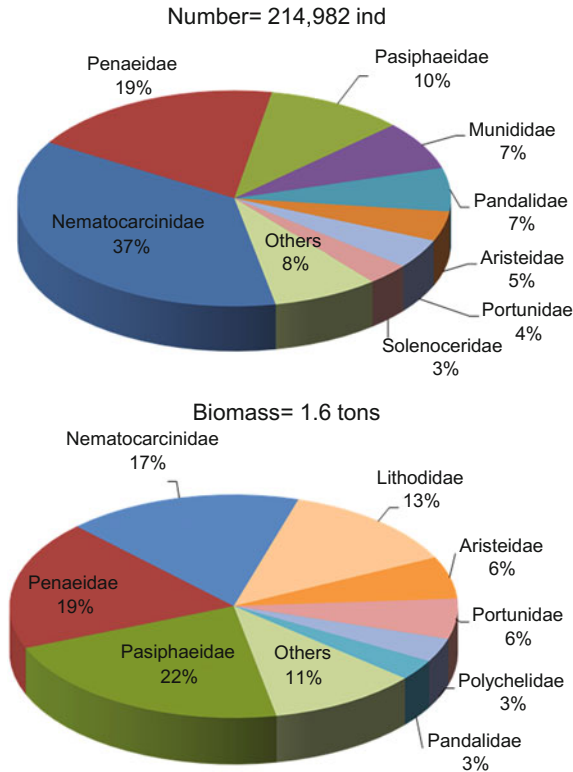
Number= 214,982 ind

Biomass= 1.6 tons

Fig. 9.4 Global composition, in numerical abundances (N) *(top)* and biomass (B, in kg) *(bottom)* standardized to 0.1 km^2 (in %) of the main decapod families in Mauritanian deep-waters

while a patchy distribution was also found in the south. The highest biomasses in this zone were found in the southernmost area and also between 200 and 1000 m depth (Fig. 9.5). Diversity revealed a similar pattern along the entire Mauritanian coast, with the lowest values on the deep shelf and upper slope (<500 m) and the highest on the slope, between 500 and 1500 m, mainly off the Arguin Bank (Fig. 9.5).

Table 9.2 shows N and B values and percentages of the dominant decapod species in the *Maurit* surveys, which together accounted for roughly 70% of the total; these species appeared in more than 30% of the trawls. The other species were grouped as "others". The most abundant species was the African spider shrimp *Nematocarcinus africanus* (264,339 individuals, 36.7%), followed by the deep-water rose shrimp *Parapenaeus longirostris* (186,773 individuals, 19.1%), the squat lobster *Munida speciosa* (74,519 individuals, 7.3%) and the kangaroo shrimp *Glyphus marsupialis* (50,077 individuals, 7.2%). Five species constituted around 70% of the total biomass: *P. longirostris* and *G. marsupialis* (around 297 kg, 18% each), *N. africanus* (270 kg, 17%), the king crab *Neolithodes asperrimus* (168 kg, 10.6%) and the striped red shrimp *Aristeus varidens* (96 kg, 6.1%).
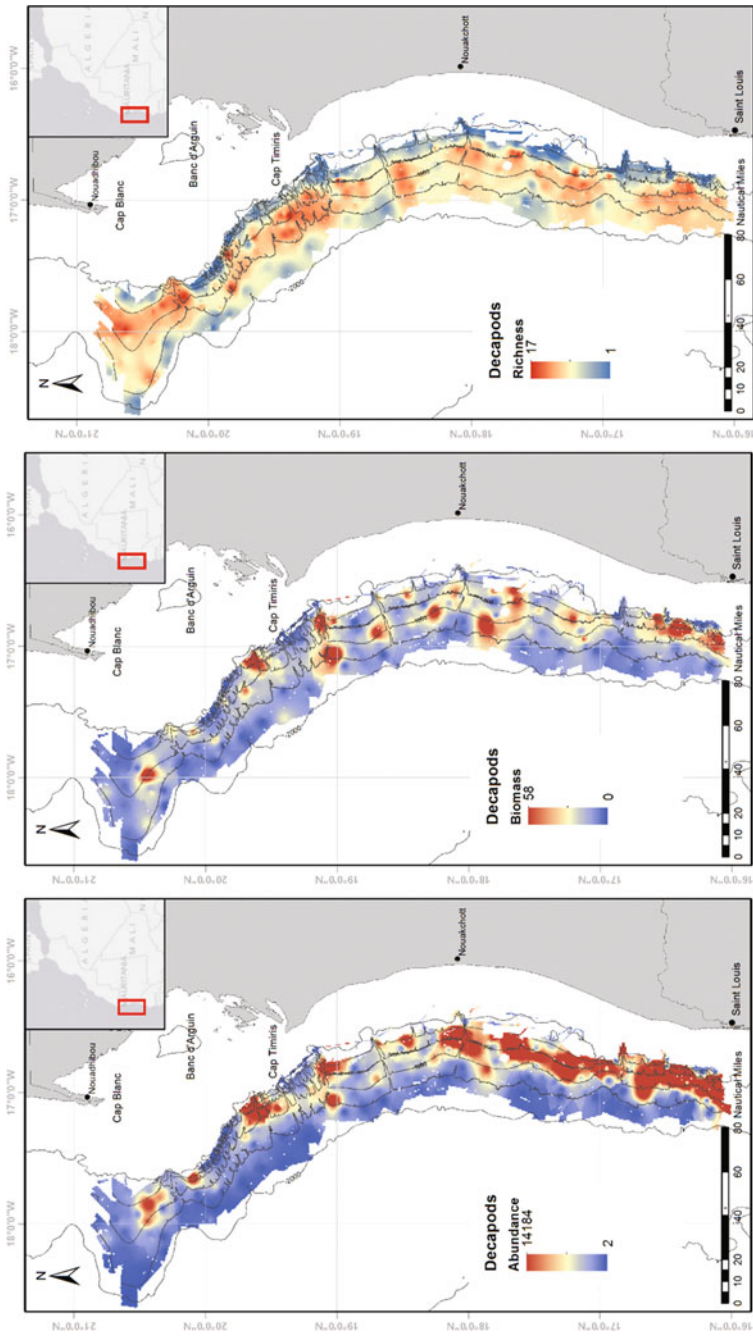
Fig. 9.5 Geographical distribution by station of numerical abundances (N) (*left*), biomass (B, in kg) (*centre*) and specific richness (S) (*right*) (data standarized to a 0.1 km² swept area)

The deep-sea shrimp *Acanthephyra pelagica* was the most common species, present in 57% of the hauls, followed by the solenocerid shrimp *Hymenopenaeus chacei* (50%), *Glyphus marsupialis* (44%), the fewspine spinytail *Systellaspis debilis*, *Aristeus varidens* and the blind lobster *Stereomastis talismani* (37–38%). All species showed a similar bathymetric range oscillating between 300 and 1900 m. Of the species collected, 20% could be considered anecdotal, as they were only found at one station in all four surveys.

Structure of the Assemblages

The MDS plot (stress = 0.08; Fig. 9.6) and the dendrogram generated by the multivariate analysis (Fig. 9.7) demonstrated that the decapod assemblages were strongly influenced by depth. A first branching at a low similarity level (below 5%)

Table 9.2 Numerical abundance (N), biomass (B, in kg) and occurrence (O, species with presence in >30% of stations), of the dominant decapods in the *Maurit* surveys

| Species	N	N (%)	Species	B (kg)	B (%)	Species	O (%)
Nematocarcinus africanus	264339	36.7	*Parapenaeus longirostris*	297	18.8	*Acanthephyra pelagica*	56.9
Parapenaeus longirostris	186773	19.1	*Glyphus marsupialis*	296	18.7	*Hymenopenaeus chacei*	49.8
Munida speciosa	74510	7.3	*Nematocarcinus africanus*	270	17.0	*Glyphus marsupialis*	43.8
Glyphus marsupialis	50077	7.2	*Neolithodes asperrimus*	168	10.6	*Systellaspis debilis*	38.8
Others (114 spp)	742685	29.6	*Aristeus varidens*	96	6.1	*Aristeus varidens*	37.4
			Others (113 spp)	457	28.8	*Stereomastis talismani*	36.7
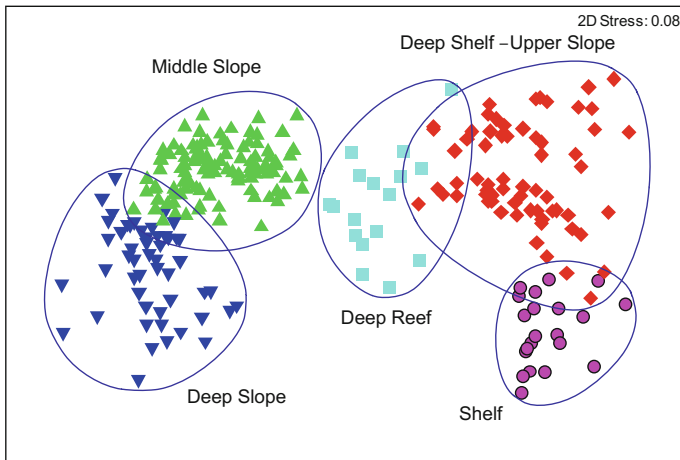
Fig. 9.6 Two-dimensional multidimensional scaling (MDS) plot of the average abundance data of decapod crustaceans obtained during the *Maurit* surveys. *Filled circle* Sh: Shelf; *Filled diamond* DS-US: Deep Shelf-Upper Slope; *Filled square* DR: Deep Reef; *Filled triangle* MS: Middle Slope; *Inverted Filled triangle* DS: Deep Slope
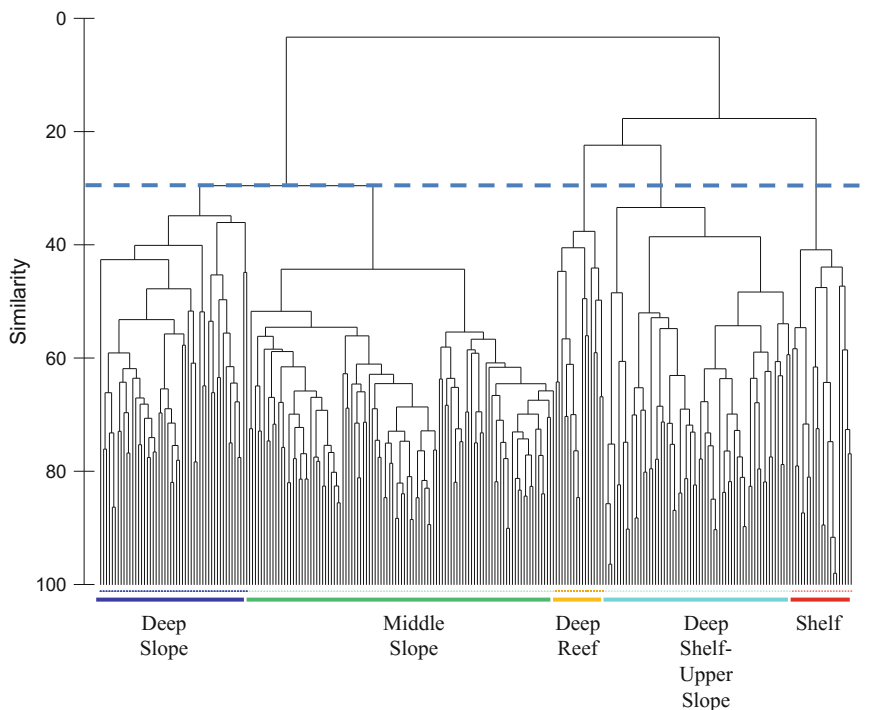
Fig. 9.7 Dendrogram resulting from multivariate analysis based on densities matrix of decapods species (numerical abundances by station standardized to 0.1 km^2 swept area) using group-average clustering from Bray-Curtis similarity index

Table 9.3 ANOSIM test results: R values between the five assemblages identified by the cluster analysis, at a significance level of 0.1%

Assemblage	Sh	DSh-US	DR	MS
DSh-US	0.67			
DR	0.98	0.66		
MS	1.00	0.99	0.90	
DS	1.00	0.99	0.98	0.72

Acronyms of assemblages: *Sh* Shelf; *DSh-US* Deep shelf-Upper slope; *DR* Deep Reef; *MS* Middle Slope; *DS* Deep Slope

Table 9.4 Summarized results of the SIMPER analysis

Assemblage	Sh	DSh-US	DR	MS
DSh-US	80.23			
DR	90.13	77.60		
MS	99.76	98.30	80.84	
DS	100. 00	99.77	92.98	70.46
DSh-US	*P. longirostris* 32.00			
DR	*P. semispinosa* 12.78	*N. africanus* 12.17		
MS	*G. marsupialis* 9.81	*P. longirostris* 12.89	*N. africanus* 9.93	
DS	*M. speciosa* 16.04	*P. longirostris* 18.39	*N. africanus* 10.14	*A. varidens* 10.74

Average of dissimilarity between the five assemblages and contribution of the main discriminating decapod species. Acronyms of assemblages: *Sh* Shelf; *DSh-US* Deep shelf-upper slope; *DR* Deep reef; *MS* Middle slope; *DS* Deep slope

discriminates two main groups, characterizing the shelf-upper slope and the middle-deep slope. At a similarity level of 30%, five groups are clearly discriminated (depth ranges are approximate): (1) a group composed by hauls down to 100 m depth ("Shelf", Sh); (2) a group of stations ranging between 100 and 400 m depth, corresponding to the "Deep shelf-Upper slope" (DSh-US); (3) the "Deep Reef" group (DR), consisting of hauls carried out near the deep-water coral mounds reef, from 400 to 550 m; (4) a group of deep stations between 550 and 1400 m ("Middle Slope", MS); and (5) another slope group including the deepest stations up to 1825 m depth ("Deep Slope", DS). The overall value of the ANOSIM test (R = 0.89) proved that these five assemblages were statistically different (Table 9.3).

The SIMPER analysis showed that the average dissimilarity between the five assemblages ranged from 70.5 to 100% (Table 9.4), the MS assemblage being the most homogeneous with an average similarity of 52% (Table 9.5). Table 9.4 shows the species responsible for the intergroup dissimilarities. Mean abundance, similarity percentage of contribution and cumulative percentages of each species in the five assemblages are shown in Table 9.6. Pictures of some of the main species are shown in Fig. 9.8.

Munida speciosa is clearly the discriminating species of the Sh assemblage (>82%), with small contributions of *Plesionika heterocarpus* and *Homola barbata*. This squat lobster is also the dominant species in terms of abundance, biomass and occurrence (Table 9.6), and is ubiquitous in this assemblage.

Four species, *Parapenaeus longirostris*, *Plesionika heterocarpus*, *Munida speciosa* and *Macropipus rugosus*, typified the DSh-US group. The dominant deep-water rose shrimp was also the main contributor species (58%) (Table 9.4), accounting for around 63% of both abundance and biomass (Table 9.6) and occurring at most stations of this assemblage (F = 95%).

Table 9.5 Most important species, in terms of percentage contribution to the group similarity, (SIMPER analysis) listed for each group resulting from the cluster analysis

Assemblage *Species*	Av. Ab.	Av. Sim	Contr. %	Cum %
Shelf (83-100 m)		47.78		
Munida speciosa	4.38	39.25	82.14	82.14
Plesionika heterocarpus	1.29	2.12	4.43	86.57
Homola barbata	0.62	1.91	4.00	90.56
Deep Shelf - Upper slope (100-400 m)		44.49		
Parapenaeus longirostris	7.32	25.78	57.94	57.94
Plesionika heterocarpus	3.35	7.33	16.48	74.43
Munida speciosa	2.85	5.55	12.46	86.89
Macropipus rugosus	1.87	2.23	5.01	91.90
Deep Reef (400-550 m)		44.42		
Pasiphaea semispisona	4.89	8.74	19.68	19.68
Solenocera africana	3.34	6.31	14.21	33.89
Nematocarcinus africanus	6.69	5.42	12.21	46.09
Plesionika carinata	3.96	5.38	12.12	58.21
Plesionika acanthonotus	3.17	4.89	11.00	69.21
Munida speciosa	2.31	3.27	7.36	76.58
Parapenaeus longirostris	3.03	3.12	7.02	83.60
Hymenopenaeus chacei	1.74	1.54	3.47	87.07
Plesionika martia	1.69	1.30	2.92	89.99
Middle Slope (550-1400 m)		52.07		
Acanthephyra pelagica	3.82	9.10	17.47	17.47
Aristeus varidens	4.33	8.68	16.67	34.14
Glyphus marsupialis	4.30	8.13	15.61	49.75
Hymenopenaeus chacei	3.57	7.08	13.61	63.36
Stereomastis talismani	2.65	4.75	9.12	72.48
Systellaspis debilis	2.07	3.50	6.72	79.20
Nematocarcinus africanus	3.11	2.14	4.12	83.31
Heterocarpus grimaldii	1.50	1.96	3.76	87.08
Sergia robusta	1.13	1.96	3.76	87.08
Plesionika carinata	1.43	0.99	0.42	89.68
Deep Slope (1400-1825 m)		45.29		
Acanthephyra pelagica	2.80	12.12	26.76	26.76
Pasiphaea tarda	2.16	5.90	13.02	39.78
Stereomastis nana	1.71	4.72	10.42	50.20
Hymenopenaeus chacei	1.88	4.17	9.21	59.41
Benthesicymus barletti	1.61	3.84	8.49	67.90
Stereomastis sculpta	1.66	3.67	8.11	76.01
Neolithodes asperrimus	1.15	2.95	6.52	82.52
Systellaspis debilis	1.01	2.02	4.47	86.99
Glyphus marsupialis	1.10	1.47	3.26	90.25

A cut-off at a cumulative similarity of 90% was applied to the data analysis

Table 9.6 Percentage of decapods abundance, biomass and occurrence within the five assemblages

Assemblage/*Species*	N (%)		B (%)		O (%)
Shelf (83-100 m) Sim: 47.8					
Munida speciosa	74.1	*Munida speciosa*	80.0	*Munida speciosa*	100.0
Others (28 spp)	25.9	Others (28 spp)	20.0	*Homola barbata*	33.3
				Macropodia gilsoni	33.3
				Pagurus cuanensis	33.3
				Plesionika heterocarpus	33.3
Deep Shelf – Upper slope (100–400 m) Sim: 44.5					
Nematocarcinus africanus	62.9	*Parapenaeus longirostris*	63.4	*Parapenaeus longirostris*	95.3
Macropipus rugosus	15.5	*Macropipus rugosus*	19.8	*Plesionika heterocarpus*	67.2
Others (48 spp)	21.6	Others (48 spp)	16.8	*Munida speciosa*	56.3
				Solenocera africana	37.5
				Macropipus rugosus	32.8
				Pasiphaea semispinosa	31.3
Deep Reef (400–550 m) Sim: 44.4					
Nematocarcinus africanus	81.6	*Nematocarcinus africanus*	69.4	*Pasiphaea semispinosa*	88.2
Others (40 spp)	18.4	*Parapenaeus longirostris*	6.5	*Solenocera africana*	88.2
		Others (39 spp)	24.1	*Plesionika acanthonotus*	82.4
				Plesionika carinata	76.5
				Munida speciosa	70.6
				Nematocarcinus africanus	64.7
				Parapenaeus longirostris	64.7
				Bathynectes piperitus	52.9
				Hymenopenaeus chacei	52,9
				Plesionika martia	52.9
				Aegaeon lacazei	35.3
				Aristeus varidens	35.4
				Sergia sp	35.5
Middle Slope (550-1400 m) Sim: 52.1					
Nematocarcinus africanus	47.2	*Glyphus marsupialis*	38.5	*Acanthephyra pelagica*	99.0
Glyphus marsupialis	17.3	*Nematocarcinus africanus*	20.2	*Glyphus marsupialis*	93.3
Aristeus varidens	10.8	*Aristeus varidens*	12.9	*Aristeus varidens*	92.4
Others (61 spp)	24.7	Others (61 spp)	28.4	*Hymenopenaeus chacei*	92.4
				Stereomastis talismani	78.1
				Systellaspis debilis	74.3
				Heterocarpus grimaldii	54.3
				Sergia robusta	48.6
				Nematocarcinus africanus	45.7
				Pasiphaea multidentata	41.0
				Plesionika carinata	41.0
				Psathyrocaris fragilis	37.1
Deep Slope (1400–1825 m) Sim:45.3					
Parapagurus pilosimanus	42.5	*Neolithodes asperrimus*	55.7	*Acanthephyra pelagica*	96.1
Hymenopenaeus chacei	9.8	*Pasiphaea tarda*	12.5	*Pasiphaea tarda*	72.5
Glyphus marsupialis	7.4	*Parapagurus pilosimanus*	8.7	*Benthesicymus bartletti*	64.7
Acanthephyra pelagica	7.0	Others (40 spp)	23.1	*Hymenopenaeus chacei*	64.7
Pasiphaea tarda	6.5			*Neolithodes asperrimus*	58.8
Others (38 spp)	26.8			*Stereomastis sculpta*	58.8
				Stereomastis nana	56.9
				Systellaspis debilis	47.1
				Acanthephyra eximia	39.2
				Glyphus marsupialis	39.2
				Stereomastis talismani	37.3

Occurrence (O) is presented for species with values >30%

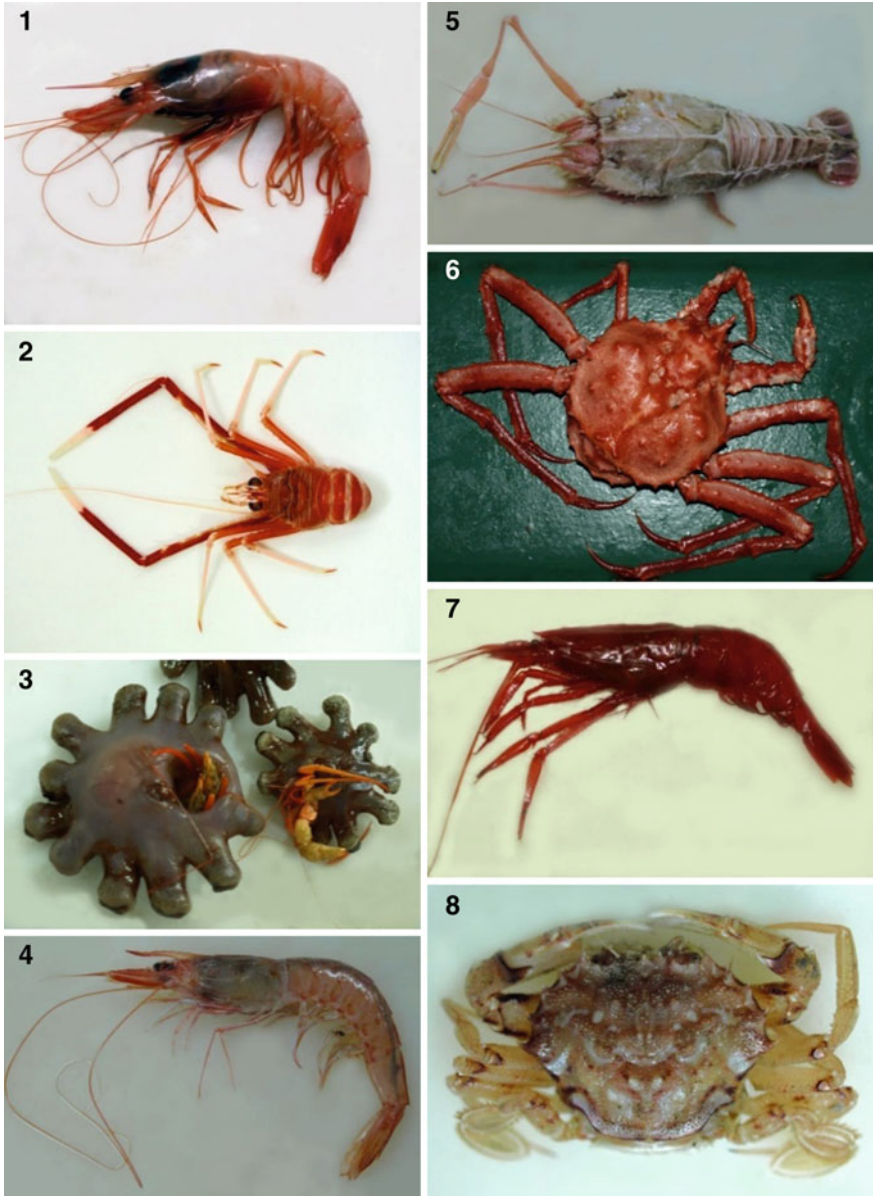**Fig. 9.8** Pictures of some of the most representative decapod species on the deep shelf and continental margin off Mauritania: *Aristeus varidens* (*1*), *Munida speciosa* (*2*), *Parapagurus pilosimanus* (*3*), *Parapenaeus longirostris* (*4*), *Stereomastis talismani* (*5*), *Lithodes ferox* (*6*), *Glyphus marsupialis* (*7*), *Macropipus rugosus* (*8*) (© Ana Ramos)

Ten species contribute to the similarity in the DR assemblage and five account for 70% of this contribution (in decreasing order): *Pasiphaea semispinosa*, the African mud shrimp *Solenocera africana*, *Nematocarcinus africanus*, and the pandalid shrimps *Plesionika carinata* and *Plesionika acanthonotus*. Other species contributing, to a lesser extent, to group similarity were *Munida speciosa*, *Parapenaeus longirostris*, *Hymenopenaeus chacei*, the golden shrimp *Plesionika martia* and the deep-water crab *Bathynectes piperitus* (lower than 7%). The African spider shrimp *N. africanus* was by far the most dominant species in the DR assemblage, in terms of abundance (82%) and biomass (69%) (Table 9.5), but not in occurrence (65%), unlike most of the above-mentioned typifying species, whose occurrences were higher than 70%.

The MS community is also typified by ten species, which most contribute to group similarity (in decreasing order): *Acanthephyra pelagica, Aristeus varidens*, *Glyphus marsupialis* and *Hymenopenaeus chacei* (together accounting for 63%), *Stereomastis talismani*, *Systellaspis debilis*, *Nematocarcinus africanus, Heterocarpus grimaldii*, the sergestid shrimp *Sergia robusta* and *Plesionika carinata* (contribution lower than 10% each). In the MS, the first four contributing species were virtually ubiquitous, with occurrences ranging from 92 to 99% (Table 9.6). *Nematocarcinus africanus* and *G. marsupialis* were the dominant species of this assemblage, both in terms of abundance (47 and 17%, respectively) and biomass (20 and 38.5%, respectively). The striped red shrimp *A. varidens* was the third species in abundance (11%) and biomass (13%) of the MS assemblage.

Nine species characterized the DS assemblage: *Acanthephyra pelagica*, *Pasiphaea tarda*, the polychelid blind lobster *Stereomastis nana* and *Hymenopenaeus chacei* (together, the four contributed to approximately 60% of the group similarity), the benthesicymid shrimp *Benthesicymus bartletti*, the flat-back lobster *Stereomastis sculpta, Neolithodes asperrimus*, *Systellaspis debilis* and *Glyphus marsupialis* (9–3% contribution). The king crab *N. asperrimus* was the most important species in terms of biomass (56%), while the anemone crab *Parapagurus pilosimanus* was the most abundant species (43%) (Table 9.6). The most typifying species, the pelagic shrimp *A. pelagica*, was virtually ubiquitous in the DS assemblage (F = 96%).

In general, decapod diversity indices increased with depth, the highest H′ and J′ occurring in the deep slope. Minimum values were registered in the DR assemblage (Table 9.7). Abundance and biomass increased with depth, from the minimal values of the Sh to their maxima in the DR assemblage, subsequently decreasing to the deepest waters.

The BEST results showed the bottom temperature as the main variable structuring the decapod assemblages off Mauritania. In fact, it offered the best correlation figures in all the abiotic variable matches and was highly correlated with longitude ($\rho = 0.85$), latitude ($\rho = 0.83$) and organic matter content ($\rho = 0.75$) (Table 9.8). Draftsman's plots had previously shown that longitude, bottom temperature and organic matter were highly correlated with depth (negatively correlated with longitude and bottom temperature and positively correlated with organic matter content).

Table 9.7 Mean values of ecological indices for the five decapod assemblages identified by the multivariate analysis: species richness (S), numerical abundance (N), biomass (B, in kg), Shannon-Wiener diversity index (H′) and Pielou index (J′) (abundance and biomass standarized to a 0.1 km^2 swept area)

Assemblage	S	N	B	H′	J′
Sh	30	122	0.5	1.4	0.29
DSh-US	50	1173	8.2	1.8	0.33
DR	41	2649	10.0	1.2	0.23
MS	64	753	6.4	2.6	0.44
DS	43	126	3.5	3.1	0.56

Acronyms of assemblages: *Sh* Shelf; *DSh-US* Deep shelf-upper slope; *DR* Deep reef; *MS* Middle slope; *DS* Deep slope

Table 9.8 Results of BIOENV analysis: Best matches of biotic and abiotic similarities matrices for each combination of variables (No)

No	ρ	Best variables correlation
1	0.848	BT
2	0.848	BT, Long
2	0.826	BT, Lat
3	0.823	BT, Long, Lat
2	0.745	BT, OM
3	0.745	BT, Long, OM
3	0.741	BT, Lat, OM
4	0.740	BT, Long, Lat, OM
3	0.717	BT, Long, Depth
3	0.717	BT, Lat, Depth

Depth, longitude (Long), Latitude (Lat), Bottom temperature (BT) and % Organic matter (OM). Spearman rank correlation (ρ)

Discussion

Decapod Diversity

With 118 species, decapods are the most diverse macrobenthic group in Mauritanian waters (see Chaps. 7 and 8). The caridean shrimps are the most diversified taxon, which concurs with previous records from deep Atlantic waters

off western Africa (Crosnier and Forest 1973; Macpherson 1991; Muñoz et al. 2012) and from the Mediterranean (Maynou et al. 1996; Maynou and Cartes 2000; Politou et al. 2005; Follesa et al. 2009; Ramírez-Llodra et al. 2010). The highest diversity of caridean shrimps in deep waters has also been reported at relatively similar latitudes of the Western Atlantic (Escobar-Briones et al. 2008). Oplophoridae were the most diverse, as also occurs in deep waters of both the Eastern and Western Atlantic (Macpherson 1991; Escobar-Briones et al. 2008).

Although it is difficult to compare species richness between the different zones studied, due to differences in the bathymetric ranges sampled and/or sampling gears, habitats, etc., in general, decapods from Mauritanian waters show a higher diversity than those observed in other Atlantic areas (Macpherson 1991; Serrano et al. 2011; Cartes et al. 2014) and much higher than in some areas of the Mediterranean, where wide bathymetric ranges were prospected (i.e., Cartes and Sardà 1992; Company et al. 2004).

However, the Mauritanian decapod diversity figures (S = 118 and H′ = 3.22) strongly resemble those recorded in a similar study carried out in Guinea-Bissau (S = 122 and H′ = 3.30) (Muñoz et al. 2012), but within different depth ranges, from 20 to 1000 m in Guinea-Bissau, and from 80 to 1800 m in Mauritania. Even when comparing a common bathymetric range of 80–1000 m in both studies, the diversity values of Mauritania (S = 93 and H′ = 2.71) are quite similar to those of Guinea-Bissau (S = 89 and H′ = 2.93) (García-Isarch, Spanish Institute of Oceanography, unpublished data, 2014). Despite the similar global diversity of decapods in both West African areas, there are faunal differences, some of which could be explained by the presence of species distributed at depths not sampled in one area or another. For instance, the brachyuran crabs showed a much lower diversity in Mauritania than in Guinea-Bissau (27 vs. 44 species), as most Guinea-Bissauan brachyurans were recorded in shallow waters, not prospected in Mauritania. The decreasing trend of brachyurans with depth, both in diversity (Soto 1991) and in abundance and biomass (Escobar-Briones et al. 2008), has been previously reported in other areas from approximately 600 m depth, probably due to the high trophic level of this group and the more limited food availability in deep waters. When the same bathymetric range is compared in Mauritania and Guinea-Bissau, certain species only occur in the waters of one country. In this case, differences are probably more related to the latitudinal distribution of each species, with a dominance of tropical species in Guinea-Bissau and a mixture of temperate and tropical species in Mauritania, whose waters are in a transitional region between these two biogeographical provinces (Maurin 1968; Domain 1980).

When waters deeper than 700 m are considered exclusively, decapod richness values found in Mauritania (S = 65) strongly resemble those of other areas in the Northeastern Atlantic (S = 67) (Cartes et al. 2014), but are higher than in the Western Mediterranean (S = 58) (Cartes et al. 2009b). However, in the Mauritanian deep slope the diversity is much higher than that estimated at similar depths in the Northeastern Atlantic (Cartes et al. 2014) (H′ 3.1 vs. 1.99). At similar depths,

the number of species found in the middle slope (S = 64) is greater in Mauritania than in other areas such as the Northwest Mediterranean Sea (S = 40) (Papiol et al. 2012), which concurs with the lower representation of decapods (Cartes 1993) and other faunal groups reported for the Mediterranean in relation to NE Atlantic waters (see examples in Cartes et al. 2004). The low diversification of Mediterranean deep-sea fauna was related to the Messinian salinity crisis that drove most marine benthic species to extinction. The recolonization of the Mediterranean by Atlantic species once the Strait of Gibraltar reopened (5 million years ago) was limited by the physical barrier constituted by the shallowness of the Gibraltar sill (Pérès 1985), together with the biological filters constituted by the hydrological characteristics of Mediterranean waters. Both factors contribute to the lower diversity of benthic groups in the Mediterranean.

Species richness is influenced by latitude and is highest in tropical and sub-tropical regions when compared to temperate and cold ones, where there is a significant decrease (Abele 1982). However, as explained above, Mauritanian decapod diversity is exceptionally high compared with other temperate regions and very close to that described in similar studies carried out in tropical areas (Muñoz et al. 2012). On the one hand, this could be explained by the special hydrographic conditions of the area, where the marked seasonality of upwellings and the latitudinal displacement of the marine front along the Mauritanian and Senegalese coasts lead to important changes in environmental conditions: in a few weeks the ecosystem alternatively changes from a warm equatorial to a cold subtropical phase and vice versa (Meiners 2007). These special conditions allow for the coexistence of tropical and temperate species, enhancing global biodiversity. On the other hand, geomorphological bottom features, like the submarine canyons system and the coral mounds barrier along the Mauritanian slope (see Chap. 17), favour the heterogeneity of habitats, thereby enhancing diversity (Menot et al. 2010; Levin and Sibuet 2012).

This high diversity of Mauritanian decapods is reflected in new species and records that have been reported from the study of the decapods collected in the *Maurit* surveys. Two new decapod species have been described from the bottom trawl samplings: *Munidopsis anaramosae* (Matos-Pita and Ramil 2014), from north Mauritania, off the Arguin Banc at 1000 m depth, and *Paguristes candelae* (Matos-Pita and Ramil 2015), from south Nouakchott at 376 m. Other new species were described from samples coming from rock dredges during the *Maurit* surveys: the crab *Neopilumnoplax corallicola* (Matos-Pita and Ramil 2016) and the thalassinidean *Ezaxius ferachevali* (Matos-Pita and Ramil 2015), which constitutes a new genus and a new species. In addition, the known bathymetric and geographical distribution ranges have been extended for some lithodid species (Muñoz and García-Isarch 2013), squat lobsters (Matos-Pita and Ramil 2014), brachyuran crabs (Matos-Pita et al. 2016), thalassinideans (Matos-Pita and Ramil 2015) and hermit crabs (Matos-Pita and Ramil 2015).

Decapod Assemblages

Five decapod assemblages, corresponding to the shelf, deep shelf-upper slope, deep reef, middle slope and deep slope, were identified in Mauritanian waters.

The structure of the shelf assemblage (81–100 m), strongly dominated by the squat lobster *Munida speciosa* has not been previously reported at similar depths in other areas, where it is the main indicator of deeper assemblages (200–300 m in Guinea-Bissau and 200–400 m in Namibia) (Muñoz et al. 2012 and Macpherson 1991). In our study, *M. speciosa* was also recorded up to 600-m depth, but as a minor contributor of deeper assemblages.

The deep shelf-upper slope assemblage (100–450 m) is clearly characterized by the dominance of the deep-water rose shrimp *Parapenaeus longirostris*, a typical deep shelf-upper slope species, also reported in the same bathymetric range in waters off Namibia (Macpherson 1991), Angola (Bianchi 1992b), Congo and Gabon (Bianchi 1992a) and Guinea-Bissau (Muñoz et al. 2012). This was the most important decapod species, in terms of biomass, of the four *Maurit* surveys. It is worth mentioning that *P. longirostris* is the main target species for the Spanish shrimper fleet in Mauritanian waters and that other contributor species of this assemblage, such as *Plesionika heterocarpus* and *Munida speciosa*, are found in the discards produced by this fleet at these depths (García-Isarch, Spanish Institute of Oceanography, unpublished data, 2011, 2012). The specific composition of this Mauritanian decapod assemblage is quite similar to that identified in Guinea-Bissau between 200 and 300 m (Muñoz et al. 2012), although the contribution of each species differs greatly from one area to another. Certain similarities are also found with the decapod community described on the Namibian northern slope (Macpherson 1991).

The deep-reef assemblage (400–550 m) is typified by a number of species, of which *Pasiphaea semispinosa*, *Solenocera africana*, *Nematocarcinus africanus* and *Plesionika carinata* are the greatest contributors. The species composition of this assemblage shows certain similarities with the Guinea-Bissauan assemblage identified between 300 and 500-m depth (Muñoz et al. 2012). *Nematocarcinus africanus*, *Munida speciosa*, *Parapenaeus longirostris* and *Plesionika martia* are common species of these assemblages in both areas, although their percentage of contribution differs between areas. The African spider shrimp *N. africanus* is the third typifying species and the main species in terms of abundance and biomass in the Mauritanian deep-reef assemblage. This species contributes to 45.2% of the assemblage identified between 300 and 500 m in waters off Guinea-Bissau and is also an indicator of the slope assemblage at 300–400 m depth in Congo, Gabon and Angola (Bianchi 1992a, b).

Acanthephyra pelagica, *Aristeus varidens*, *Glyphus marsupialis* and *Hymenopenaeus chacei* are the main contributor species of the middle slope assemblage (550–1400 m), followed by other species, such as *Stereomastis talismani*, *Systellaspis debilis*, *Nematocarcinus africanus*, *Heterocarpus grimaldii* and *Sergia robusta*. Some of these species are common to the Namibian slope/bathyal decapod

assemblage (Macpherson 1991) and to the Guinea-Bissauan deep-slope assemblage (500–1000 m) (Muñoz et al. 2012), although the general assemblage structures are quite different in these three areas. It is worth mentioning the relative importance of the striped red shrimp *A. varidens*, the third species in landings from the European Union shrimp fleet operating in Mauritania, specifically targeted at depths around 600–750 m (García-Isarch, Spanish Institute of Oceanography, unpublished data, 2011, 2012).

Some of the typifying species of the deep-slope assemblage (1400–1825 m) belong to the families Oplophoridae (*Acanthephyra pelagica*, *Systellaspis debilis*), Pasiphaeidae (*Pasiphaea tarda*, *Glyphus marsupialis*), Polychelidae (*Stereomastis nana, Stereomastis sculpta*) and Lithodidae (*Neolithodes asperrimus*), which are also the most representative families of the deep-slope assemblages found in other Atlantic regions, such as the Galicia Bank in the NE Atlantic (Cartes et al. 2014). *Acanthephyra pelagica, S. sculpta* and other species of *Hymenopenaeus* genus are also representative species in the deep-slope assemblages of Mediterranean areas (Cartes and Sardà 1993; Maynou and Cartes 2000).

The affinities found within families, genus or even species between the decapod deep assemblages of Mauritania and those of other Atlantic and Mediterranean areas are probably due to a common origin of the deep-sea fauna (Cartes 1993), whereas differences can be attributable to the intrinsic characteristics of each area studied. The uniqueness of the assemblage structure can be better explained by the combination of local environmental factors and the biogeographical history of the region considered (Maynou and Cartes 2000).

Environmental Variables Influencing Mauritanian Decapod Communities

Depth and depth-dependent variables, together with latitude, seem to be the main causes structuring decapod assemblages on the Mauritanian shelf and continental slope, as observed in other areas of the Atlantic (Lleonart and Roel 1984; Macpherson 1991; Fariña et al. 1997; Muñoz et al. 2012) and the Mediterranean (Abelló et al. 2002; Cartes and Sardà 1993; Company et al. 2004; Fanelli et al. 2007; Follesa et al. 2009; Papiol et al. 2012). However, depth should be considered as a proxy for a combination of several environmental variables affecting organisms (Papiol et al. 2012). In fact, depth is not a causative factor and other variables, such as temperature, high pressure, food availability and turbidity, have also been proposed causes of faunistic changes in the bathymetric gradient (Carney 2005; Fanelli et al. 2013; Cartes et al. 2014). In our study, other depth-related physical and ecological variables, such as bottom temperature and organic matter content, seem to play an important role in structuring decapod assemblages. In general, temperature has been suggested as a primary cause influencing faunal zonation in deep-sea communities (Gage and Tyler 1991) and organic matter content has been identified

as one of the most dominant variables affecting the distribution of deep-sea decapods (Cartes et al. 2007). Other factors not strictly related to depth clearly influence the existence of certain decapod communities, as is the case for the deep-reef assemblage. This cold-water coral) mounds barrier (described in detail in Chap. 13) runs over 400 km parallel to the shelf break along the Mauritanian slope between the Senegalese border and Cape Timiris. It is a carbonate mound reef mainly composed of dead coral (*Lophelia pertusa*) and small amounts minor proportions of *Madrepora oculta*. The presence of this giant structure together with an oxygen minimum zone (OMZ) at the same depths (400–550 m) constitute the main faunistic boundary in the Mauritanian slope (see Chaps. 7 and 17) and may have contributed to the existence of a specific decapod assemblage. Dissolved oxygen concentration has been recognized as a major limiting factor for benthic and demersal species, since low oxygen concentrations (i.e., below 2.0 ml l^{-1}) may affect most marine invertebrates (Rosenberg et al. 1991; Diaz and Rosenberg 1995). Decapods seem to be the only faunal group able to adapt to this ecosystem.

In Mauritania, the biomass and abundance of decapods increase with depth from the shelf (minimum values) to the deep reef, peaking at 400–550 m depth, decreasing beyond these depths until reaching new minima values on the deep slope. Surprisingly, the greatest concentrations of decapods in the deep reef are found at depths recording minimum values of oxygen (1.0–1.3 ml l^{-1} between 300 and 550 m), along practically all the Mauritanian coast, from Cape Timiris to the Senegalese border (see Chap. 3). This coincidence of the highest decapod biomass with oxygen minimum values and maximum turbidity near the bottom is also reported in the Mediterranean (Fanelli et al. 2013), although oxygen minimum values in these waters (around 4.0–4.2 ml l^{-1} between 450 and 550 m) are not so limiting as in Mauritania. In the Mediterranean, the assemblage recording the highest decapod biomass occurring in the minimum oxygen zone was also the most diverse. However, the Mauritanian deep-reef assemblage recorded the minimum diversity values despite its highest biomass. Certain decapods, especially deep-shrimp species, seem to be less sensitive to low oxygen values than other groups, as described for some deep-sea shrimp genera (i.e., *Solenocera*, *Nematocarcinus* and *Plesionika*) in the Mexican Pacific (Hendrickx and Serrano 2010), where this capacity seems to be an ecological advantage, since it reduces competition for space and food with other groups that are much more sensitive to these adverse conditions. Our results show that the highest abundance and biomass of the deep-reef assemblage are mainly attributed to one single species, the *Nematocacinus africanus*. This dominance also explains the low diversity of this assemblage. Beyond 550 m, decapod abundance and biomass exhibited the typical decrease observed in deep-sea environments (Haedrich et al. 1980; Cartes and Sardà 1992; Company et al. 2004; Politou et al. 2005; Cartes et al. 2007; Follesa et al. 2009; Fanelli et al. 2013), in agreement with the well-established general pattern for deep-sea benthos associated with low food availability in deep bottoms (Rowe 1983; McClain et al. 2008).

In Mauritanian waters, decapod diversity displays a different pattern than abundance and biomass, generally increasing with depth and peaking over the deep

slope, between 1400 and 1825 m. The increasing diversity with bathymetry is only disrupted in the deep-reef assemblage, where minimum values were recorded, in relation to the dominance of a limited number of species that are probably better adapted to low oxygen levels (i.e., *Nematocacinus africanus*). The observed increase in decapod diversity with depth is an uncommon feature, although it has already been reported in certain areas of the Mediterranean (Follesa et al. 2009). More generally speaking, maximum diversity values have been recorded for macrofauna, megafauna and fish between 1500 and 2500 m in the western North Atlantic (Rex 1983), suggesting the existence of biodiversity "hot spots" at these depths (Levin and Sibuet 2012). Several hypotheses have been proposed to explain the diversity peak observed at intermediate slope depths (1000–2500 m), including competition, predation, productivity, environmental heterogeneity and patch dynamics, as well as different combinations of them (see review in Snelgrove and Smith 2002).

Latitude also influences the assemblage structure, although it is masked by the strong effect of depth. This influence may be due to secondary variables that differ with latitude (such as those related to the oceanography and geomorphology of the area). Latitudinal patterns were also detected in the global values of decapod abundance and biomass along the Mauritanian coast—as observed for global megabenthos (Chap. 7)—generally increasing southwards. Some especially rich areas for decapods and more specifically for the deep-water rose shrimp *Parapenaeus longirostris* (García-Isarch, Spanish Institute of Oceanography, unpublished data, 2014) were located north and south of Cape Timiris, probably associated with the Arguin (North) and Timiris (South) canyon systems. In fact, these submarine structures have been suggested as the origin of organic matter inputs that form nepheloid layers in slope regions close to the canyons (Cartes et al. 2009b), enhancing the productivity of these zones. In South Cape Timiris, decapod abundance and biomass are very high, especially associated with the deep reef (in this case with the highest contribution of *Nematocarcinus africanus*) and with the deep shelf and upper slope (being *P. longirostris* the most abundant species). The differences found in biomass and abundance patterns are attributable to the size of the dominant individuals in certain areas (i.e., areas with high abundances and low biomass are dominated by small species and specimens, whereas high biomass and low abundance zones are mainly represented by large species and individuals) (García-Isarch, Spanish Institute of Oceanography, unpublished data, 2014).

In general, species tend to occupy discrete depth bands which progressively replace each other by moving from shelf to abyssal depths (Carney 2005). Thus, benthic assemblages show clear boundaries or a discontinuity pattern of distribution in the vertical gradient (Rowe 1981), which vary according to locations (Maynou and Cartes 2000). Causes of zonation have been mainly attributed to gradients in environmental parameters (i.e., light, temperature, food availability) that co-occur with depth and that affect the biology and physiology of marine organisms and the ecological interactions between taxa (Rex 1976; Rowe 1981; Carney 2005). In Mauritanian waters, the zonation of the decapod communities has bathymetric boundaries located at depths around 100, 400, 550 and 1400 m. The 100 m

boundary may be related to the upper limit of the permanent thermocline (see Chap. 3). At 400 m, the occurrence of a bottom minimum oxygen layer and the location of the great coral mounds barrier of mainly dead *Lophelia pertusa* (see Chaps. 3, 13 and 17) may favour the clearly observed species replacement occurring at that depth. The influence of the bottom low oxygen levels on the zonation of decapod assemblages was suggested by Macpherson (1991) in West African waters off Namibia. In fact, the bottom OMZ is a dispersal barrier for the continental shelf species (Hendrickx 2001) and OMZ boundaries form sub-zones with great heterogeneity of environmental variables, constituting abrupt shifts in animal communities (Sellanes et al. 2010). The 550-m depth boundary must be related to a new increase in oxygen levels (see Chap. 3), constituting a zone with a high species turnover, which is quite common in the upper slopes (around 500 m) of different areas (Carney 2005). In fact, depths around 500–650 m have also been cited as faunal boundaries for decapods in North Atlantic areas (Cartes et al. 2007) and for all invertebrates in the Western Mediterranean Sea (Cartes et al. 2009b). The faunal discontinuity found around 1400 m has been reported at similar depths (between 1200 and 1500 m) in other areas of the Atlantic (Wenner and Boesch 1979; Hecker 1990; Cartes et al. 2014) and the Mediterranean (Cartes and Sardà 1993; Cartes 1993; Fanelli et al. 2013) and is probably related to trophic factors (Cartes and Sardà 1993). This depth is considered as the beginning of the abyssal zone (Carney 2005). It is worth noting that the boundaries definition varies among different taxa (Cartes and Sardà 1993), due to their distinct trophic levels (Maynou and Cartes 2000). Different groups of fish and invertebrates may exploit different fractions of food resources and therefore show different response patterns to a depth gradient.

Conclusions

This work provides the first contribution to the knowledge of decapod communities in Mauritanian waters, including an analysis of the composition, distribution, abundance and structure of decapod assemblages.

This constitutes a reference point for assessing potential changes in the structure of the ecosystem, attributable either to changes in climate and oceanographic conditions or to anthropogenic causes, such as trawling fishing pressure.

In this sense, special attention must be given to the shelf and deep shelf-upper slope assemblages, which are more susceptible to being affected by fishing pressure, such as that currently exerted by the trawling shrimper fleet targeting *Parapenaeus longirostris* in the area at these assemblage depths.

Because of the lower resilience and higher vulnerability of the deep-sea benthic ecosystem (>200-m depth), the impact of trawling is more severe and lasts longer than in shallower areas. However, current fishing pressure beyond 350 m is somewhat diminished, due to the relative limited effort exerted by the shrimper fleet when targeting deep-sea crustaceans and to the recent, considerable reduction in the hake trawler fleet, usually operating in deeper waters.

These types of studies are useful tools for the implementation of an ecosystem-based approach to fisheries management, which reverses the order of management priorities and starts with the ecosystem rather than with the target species.

Annexe

Annexe 9.1 Taxonomic list of decapods inhabiting the Mauritanian deep shelf and continental slope and their main biological variables (*N* Numerical abundance; *B* biomass, in kg; *O* occurrence, % of stations; *DR* depth range, in m; *LR* latitudinal range, in °; *H* habitat, *B* benthic; *P* pelagic; *N* nectobenthic)

Taxa	Species	N	B (kg)	O (%)	DR (m)	LR (°)	H
Suborder Dendrobranchiata							
Superfamily Penaeoidea							
Family ARISTEIDAE	*Aristaeopsis edwardsiana* (Johnson, 1868)	53	0.54	3.2	554-1016	20.8-16.1	B
	Aristaeomorpha foliacea (Risso, 1827)	12	0.17	0.7	618-850	20.8-19.8	N
	Aristeus antennatus (Risso, 1816)	238	2.57	8.2	415-1236	20.7-16.1	N
	Aristeus varidens Holthius, 1952	30677	308.09	37.4	403-1556	20.8-16.1	B
Family BENTHESICYMIDAE	*Benthesicymus bartletti* Smith, 1882	1340	9.04	19.2	1010-1867	20.8-16.1	B
Family PENAEIDAE	*Penaeus notialis* Pérez Farfante, 1967	12	0.33	0.7	93-146	19.2-18.8	P
	Funchalia danae Burkenroad, 1940	3.2	<0.01	0.4	1195-1199	19.4-19.3	B
	Metapenaeopsis miersi (Holthuis, 1952)	5.5	<0.01	0.4	101-120	19.2	B
	Parapenaeus longirostris (Lucas, 1846)	186773	1307.24	27.8	86-803	20.6-16.1	B
	Pelagopenaeus balboae (Faxon, 1893)	6	<0.01	0.4	1656-1657	16.7	P
Family SICYONIIDAE	*Sicyonia galeata* Holthuis, 1952	3	<0.01	0.4	85-87	18.2	B
Family SOLENOCERIDAE	*Hymenopenaeus chacei* Crosnier & Forest, 1969	18792	26.14	49.8	343-1750	20.8-16.1	B
	Solenocera africana Stebbing, 1917	3898	24.92	14.2	173-861	20.7-16.1	N
Superfamily Sergestoidea							
Family SERGESTIDAE	*Eusergestes arcticus* (Kroyer, 1855)	5	<0.01	0.4	334-352	20.7	P
	Sergia grandis (Sund, 1920)	179	1.08	12.1	615-1777	20.7-16.1	P
	Sergia robusta (Smith, 1882)	1694	2.26	22.1	390-1769	20.8-16.1	P
	Sergia sp	366	0.46	7.5	311-1862	20.8-16.3	-
	Sergia talismani (Barnard, 1947)	34	0.02	0.7	390-650	20.6-17.4	P
Suborder Pleocyemata							
Infraorder Caridea							
	Caridea indet.	13	0.1	1.4	827-1435	20.5-18.7	--

(continued)

Annexe 9.1 (continued)

Taxa	Species	N	B (kg)	O (%)	DR (m)	LR (°)	H
Superfamily Alpheoidea							
Family HIPPOLYTIDAE	*Lebbeus africanus* Fransen, 1997	16	0.03	0.7	1000-1749	20.3-20	B
Superfamily Crangonoidea							
Family CRANGONIDAE	*Aegaeon cataphractus* (Olivi, 1792)	20	0.02	1.8	80-112	19.4-16.9	B
	Aegaeon lacazei (Gourret, 1887)	94	0.07	2.9	79-675	20.7-16.1	B
	Metacrangon bellmarleyi (Stebbing, 1914)	86	0.13	6.8	557-1384	20.7-16.4	B
	Parapontophilus gracilis gracilis (Smith, 1882)	51	0.04	1.4	556-1010	18.1-17.2	B
	Sabinea hystrix (A. Milne-Edwards, 1881)	47	0.62	4.3	862-1811	20.8-16.1	B
Family GLYPHOCRANGONIDAE	*Glyphocrangon longirostris* (Smith, 1882)	256	3.12	4.9	1531-1867	20.7-16.7	B
Superfamily Nematocarcinoidea							
Family NEMATOCARCINIDAE	*Nematocarcinus africanus* Crosnier & Forest, 1973	264339	909.26	24.2	173-1064	20.8-16.1	B
	Nematocarcinus ensifer (Smith, 1882)	14	0.11	0.4	1778-1811	19.4	B
Superfamily Oplophoroidea							
Family OPLOPHORIDAE	*Acanthephyra acanthitelsonis* Bate, 1888	6	0.06	0.7	1422-1685	18.1-16.7	P
	Acanthephyra curtirostris Wood-Mason & Alcock, 1891	3	<0.01	0.4	1590-1599	16.2-16.1	P
	Acanthephyra eximia Smith, 1884	237	2.89	10.3	1160-1867	20.8-16.1	N
	Acanthephyra pelagica (Risso, 1816)	12741	38.86	57.0	402-1862	20.8-16.1	P
	Ephyrina figueirai figueirai Crosnier & Forest, 1973	10	0.09	1.1	1010-1572	19.9-16.5	P
	Ephyrina sp	10	0.09	0.7	1095-1530	19.9-19.1	-
	Notostomus crosnieri Macpherson, 1984	84	0.47	8.9	774-1698	20.2-16.4	P
	Notostomus gibbosus A. Milne-Edwards, 1881	24	0.18	2.9	1308-1824	20.8-17	P
	Oplophorus spinosus (Brullé, 1839)	33	0.05	3.2	557-1598	20.7-16.8	P
	Systellaspis cristata (Faxon, 1893)	14	0.04	1.4	1178-1547	19.8-16.3	P
	Systellaspis debilis (A. Milne-Edwards, 1881)	3305	4.18	38.8	343-1862	20.8-16.1	P
	Systellaspis pellucida (Filhol, 1885)	6	<0.01	0.7	1560-1685	18.5-16.7	B

(continued)

Annexe 9.1 (continued)

Taxa	Species	N	B (kg)	O (%)	DR (m)	LR (°)	H
Superfamily Pasiphaeoidea							
Family PASIPHAEIDAE	Glyphus marsupialis Filhol, 1884	50077	961.08	43.8	334-1867	20.8-16.1	B
	Parapasiphae sulcatifrons Smith, 1884	3	0.02	0.4	1590-1599	16.2-16.1	P
	Pasiphaea multidentata Esmark, 1866	586	4.53	20	557-1683	20.8-17.6	P
	Pasiphaea semispinosa Holthius, 1951	14958	16.47	21.0	216-1667	20.8-16.1	P
	Pasiphaea tarda Kroyer, 1845	2411	119.48	22.8	1091-1867	20.7-16.1	P
	Pasiphaea sp	10	0.02	0.7	896-1160	19.6-19.4	-
	Psathyrocaris fragilis Wood-Mason & Alcock, 1893	7204	29.15	15	415-1146	20.7-16.1	B
Superfamily Pandaloidea							
Family PANDALIDAE	Heterocarpus ensifer A. Milne-Edwards, 1881	143	0.51	2.1	278-628	20.7-16.4	B
	Heterocarpus grimaldii A. Milne-Edwards & Bouvier, 1900	3270	45.12	23.1	712-1532	20.8-16.2	B
Family PANDALIDAE	Plesionika acanthonotus (Smith, 1882)	3393	9.57	9.6	252-801	20.7-16.4	N
	Plesionika brevipes (Crosnier & Forest, 1968)	6865	25.53	4.3	215-473	18.7-16.1	-
	Plesionika carinata Holthius, 1951	13849	26.26	22.1	230-1677	20.7-16.1	P
	Plesionika edwardsii (Brandt, 1851)	159	0.90	2.9	252-436	18.1-16.1	N
	Plesionika ensis (A. Milne-Edwards, 1881)	26	0.07	0.7	210-341	19.1-18.7	B
	Plesionika heterocarpus (A. Costa, 1871)	22373	52.69	21.3	86-861	20.7-16.1	N
	Plesionika martia (A. Milne-Edwards, 1883)	908	2.95	6.1	274-693	20.7-16.1	N
	Plesionika narval (Fabricius, 1787)	536	1.36	1.4	87-146	19.4-18.3	B
	Plesionika sp	71	0.08	1.1	343-626	20.7-17.9	-
Infraorder Polychelida							
Superfamily Eryonoidea							
Family POLYCHELIDAE	Stereomastis nana (Smith, 1884)	1340	15.5	10.7	1290-1867	20.8-16.1	B
	Stereomastis sculpta (Smith, 1880)	1110	22	13.9	1214-1717	20.8-16.1	B
	Stereomastis talismani (Bouvier, 1917)	7682	135	36.7	452-1717	20.8-16.1	B
	Polycheles typhlops Heller, 1862	7	0.02	0.7	464-675	20.5-17.8	B

(continued)

Annexe 9.1 (continued)

Taxa	Species	N	B (kg)	O (%)	DR (m)	LR (°)	H
Infraorder Achelata							
Superfamily Palinuroidea							
Family PALINURIDAE	*Palinurus mauritanicus* Gruvel, 1911	367	137.05	5.7	200-532	20.7-16.5	B
Family SCYLLARIDAE	*Scyllarus caparti* Holthuis, 1952	5	0.03	0.4	103	18-17.9	B
	Scyllarus subarctus Crosnier, 1970	264	1.17	4.3	88-172	20.7-16.2	B
Infraorder Astacidea							
Superfamily Nephropoidea							
Family NEPHROPIDAE	*Nephropsis atlantica* Norman, 1882	555	4.81	10	724-1317	20.7-16.3	B
Infraorder Axiidea							
Superfamily Axioidea							
Family AXIIDAE	*Calocarides coronatus* (Trybon, 1904)	3	<0.01	0.4	562-637	16.4-16.3	B
Superfamily Callianassoidea							
Family CALLIANASSIDAE	*Trypaea oblonga* (Le Loeuff and Intès, 1974)	5	<0.01	0.4	358-364	17.5	B
Infraorder Anomura							
Superfamily Chirostyloidea							
Family EUMUNIDIDAE	*Eumunida bella* de Saint Laurent & Macpherson, 1990	4	0.24	0.4	618-850	19.8	B
Superfamily Galatheoidea							
Family MUNIDIDAE	*Munida guineae* Miyake & Baba, 1970	88	0.41	0.4	452-468	16.4	B
	Munida speciosa von Martens, 1878	74510	143.33	25.9	80-606	20.7-16.1	B
Family MUNIDOPSIDAE	*Munidopsis anaramosae* Matos-Pita & Ramil, 2014	3	<0.01	0.4	1006-1012	20.3	B
	Munidopsis chunii Balss, 1913	10239	10.45	6.1	896-1862	19.9-16.4	B
	Munidopsis curvirostra Whiteaves, 1874	40	0.03	2.5	1680-1867	20.7-19.5	B
	Munidopsis serricornis (Lovén, 1852)	3	0.003	0.4	975-984	20.7	B

(continued)

Annexe 9.1 (continued)

Taxa	Species	N	B (kg)	O (%)	DR (m)	LR (°)	H
Superfamily Paguroidea							
	Paguroidea indet.	60	0.1	1.4	87-427	18.8-16.2	-
Family DIOGENIDAE	Dardanus arrosor (Herbst, 1796)	185	0.52	7.8	80-540	20.7-16.1	B
	Diogenes pugilator (Roux, 1829)	15	0.02	0.4	100-105	19.6	B
	Areopaguristes mauritanicus (Bouvier, 1906)	5	<0.01	0.4	103	18-17.9	B
	Paguristes candelae Matos Pita & Ramil, 2015	3	0.08	0.4	376-377	17.7	-
Family PAGURIDAE	Anapagurus laevis (Bell, 1846)	26	0.03	0.7	86-105	19.6-19.4	B
	Pagurus alatus Fabricius, 1775	36	0.08	2.5	80-430	20-16.1	B
	Pagurus cuanensis Bell, 1845	233	0.44	6.4	84-174	20.7-16.1	B
	Pagurus prideaux Leach, 1815	50	0.17	1.4	87-120	20.7-20.4	B
Family PARAPAGURIDAE	Paragiopagurus macrocerus (Forest, 1955)	14	0.06	0.7	322-364	20.4-18.3	B
	Parapagurus nudus (A. Milne-Edwards, 1891)	6	0.02	0.7	1659-1688	17.7-16.7	B
	Parapagurus pilosimanus Smith, 1879	10139	58.56	10.7	403-1577	20.8-16.1	B
Superfamily Lithodoidea							
Family LITHODIDAE	Lithodes ferox Filhol, 1885	103	87.45	5.7	415-1682	20.8-16.3	B
	Neolithodes asperrimus Barnard, 1947	309	518.95	16	997-1862	20.8-16.1	B
	Neolithodes grimaldii (A. Milne-Edwards & Bouvier, 1894)	13	23.11	1.1	1680-1862	20.7-19.9	B
	Paralomis cristulata Macpherson, 1988	12	1.46	1.5	744-984	20.8-17.1	B
	Paralomis erinacea Macpherson, 1988	81	14.15	3.6	1091-1347	19.4-16.2	B
Infraorder Brachyura							
Superfamily Calappoidea							
Family CALAPPIDAE	Acanthocarpus brevispinis Monod, 1946	28	2.52	1.8	274-598	18.4-16.1	B
	Calappa pelii Herklots, 1851	3	0.08	0.4	80-98	19.3-19.2	B
Superfamily Dorippoidea							
Family DORIPPIDAE	Medorippe lanata (Linnaeus, 1767)	5	<0.01	0.4	86-90	19.4	B

Annexe 9.1 (continued)

Taxa	Species	N	B (kg)	O (%)	DR (m)	LR (°)	H
Superfamily Goneplacoidea							
Family GONEPLACIDAE							
	Goneplax barnardi (Capart, 1951)	58	0.11	2.5	278-650	18.9-16.1	B
	Goneplax rhomboides (Linnaeus, 1758)	26	0.07	1.1	88-322	20-17.8	B
Superfamily Grapsoidea							
Family PLAGUSIIDAE							
	Euchirograpsus liguricus H. Milne Edwards, 1853	--	--	0.4	311	18.3	B
Superfamily Homoloidea							
Family HOMOLIDAE							
	Homola barbata (Fabricius, 1793)	106	0.37	5.3	80-404	20.7-16.1	B
	Paromola cuvieri (Risso, 1816)	137	91.69	3.9	274-850	20.7-16.1	B
Superfamily Majoidea							
Family EPIALTIDAE							
	Pisa armata (Latreille, 1803)	37	0.19	2.5	92-146	19.2-16.1	B
Family INACHIDAE							
	Inachus aguiarii de Brito Capello, 1876	30	0.05	1.8	93-112	17.1-16.1	B
	Inachus angolensis Capart, 1951	246	0.52	4.6	81-362	20.6-16.7	B
	Inachus leptochirus Leach, 1817	27	0.03	0.7	145-352	20.7-20.6	B
	Inachus nanus Manning & Holthuis, 1981	23	0.02	1.4	85-200	20-18.2	B
	Macropodia gilsoni (Capart, 1951)	154	0.15	6.1	80-189	19.6-16.1	B
	Macropodia hesperiae Manning & Holthuis, 1981	14	<0.01	1.1	80-102	19-16.9	B
	Macropodia longipes (A. Milne Edwards & Bouvier, 1899)	6	<0.01	0.4	110-112	16.3	B
	Macropodia macrocheles (A. Milne Edwards & Bouvier, 1898)	133	0.11	4.3	93-540	19.8-16.6	B
	Eurynome aspera (Pennant, 1777)	11	0.02	0.7	115-177	20-19.7	B
Family MAJIDAE							
Superfamily Leucosioidea							
Family LEUCOSIIDAE							
	Ebalia nux A. Milne Edwards, 1883	3	<0.01	0.4	271-305	20.6	B
	Pseudomyra mbizi Capart, 1951	10	0.02	0.7	163-404	19.3-16.5	B
Superfamily Parthenopoidea							
Family PARTHENOPIDAE							
	Solenolambrus noordendei (Capart, 1951)	137	0.14	2.5	86-200	20.7-18.7	B
	Spinolambrus notialis (Manning & Holthuis, 1981)	9	0.01	0.7	102-174	19.6-17	B

(continued)

Annexe 9.1 (continued)

Taxa	Species	N	B (kg)	O (%)	DR (m)	LR (°)	H
Superfamily Portunoidea							
Family GERYONIDAE	*Chaceon maritae* (Manning & Holthuis, 1981)	352	86.63	10.3	402-1390	20.8-16.1	B
Family MACROPIPIDAE	*Bathynectes piperitus* Manning & Holthuis, 1981	494	8.41	10.3	260-850	20.7-16.3	B
	Macropipus rugosus (Doflein, 1904)	30805	296.81	10.7	79-257	20.7-16.1	B
Superfamily Xanthoidea							
Family XANTHIDAE	*Monodaeus cristulatus* Guinot & Macpherson, 1988	31	0.04	1.8	100-311	19.6-16.1	B

Systematic arrangements after de Grave et al. (2009), Ahyong et al. (2010, 2011) and Schnabel and Ahyong (2010)

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