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RESEARCH PAPER

Spatio Temporal Variations in Decapod Crustacean Assemblages of Bathyal Ground in the Antalya Bay (Eastern Mediterranean)

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Abstract

The spatio-temporal distributions of decapod crustaceans caught by trawlers over the 200 m at 87 hauls on the bathyal ground in the gulf of Antalya (eastern Mediterranean) were investigated. Samples were collected during the monthly surveys from July 2010 to June 2011, and sampling area was divided in eight bathymetric strata (200-900 m: 100 m interval). Hypotheses about relationships of assemblages to depth stratum and consecutive four seasons were tested. Univariate (one- and two-way ANOVA) and multivariate analysis (Bray-Curtis, nMDS, PERMANOVA and PERMIDS tests) showed differences in crustacean assemblages (abundance, biomass and species richness) according to depth stratum. No significant differences related to the consecutive seasons were detected. Analysis of the trawl catches shows two decapod assemblages: one on the upper slope (shallower than 500 m) characterized by *Parapenaeus longirostris* and *Plesionika heterocarpus* and another on the middle slope (500-900 m) with *Aristaeomorpha foliacea, Aristeus antennatus* and *Plesionika martia*.

Keywords: Decapoda, crustacea, abundance, distribution, East Mediterranean Sea

Introduction

Decapod crustaceans are one of the most dominant megafaunal groups in the deep-sea communities of the Mediterranean Sea (Sardà, Cartes, & Company, 1994). These communities have a significant ecological importance in this basin, since present series of transverse ridges with a north-south trend. This specific marine geomorphology is found both in the western (Alboran, Balearic, Tyrrhenian basins) and the eastern part (Ionian, Aegean, Levantine) (Sardà *et al*., 2004; Palmas *et al*., 2015).

Over the years the progressive depletion of coastal fisheries resources has forced Mediterranean fishermen to search for new fishing grounds at greater depths. Large amount of scientific data has been already collected in the Mediterranean basin during the past century by several oceanographic expeditions and in recent years by the fisheries surveys funded mainly by the European Union (Bertrand, Gil De Sola, Papaconstantinou, Relini, & Souplet, 2002). Specifically, the demersal and epibenthic assemblages of trawlable grounds in the western part of the Mediterranean have been studied in details and the main factors affecting them is the depth, sediment type, food availability and environmental factors (e.g. Cartes *et al*., 2004). In the central Mediterranean Sea the exploitation of trawlable bathyal grounds dates back to the 1930s, when commercial stocks of Norway lobster and aristeid shrimps were discovered in the Ligurian Sea (Brian, 1931).

Decapod crustaceans such as *Aristaeamorpha foliacea*, *Aristeus antennatus*, *Parapenaeus longirostris* and two pandalid shrims *Plesionika martia* and *Plesionika edwardsii* are the main target species of the deep water bottom trawl fisheries off the Antalya Bay (Deval, Bök, Ateş, Ulutürk, & Tosunoğlu, 2009). In contrast to the other Mediterranean areas, the biota of the Turkish Mediterranean slope is poorly known. The existing literature on the composition and bathymetric distribution of the decapod crustaceans assemblages in the Turkish Seas is restricted mainly to the continental shelf (e.g. Katağan, Kocataş, & Benli, 1988; Ateş, Katağan, & Kocataş, 2006; Koçak, Kırkım, & Katağan, 2010; Çınar *et al*., 2012). There are no detailed and analytical studies on their abundance, diversity and distribution patterns or species fishing grounds on the bathyal ground in the Turkish Seas (eastern Mediterranean). For these above mentioned reasons, the present study examines, for the first time, the community of decapod crustaceans along the depth gradient from 200 to 900 m on the slope of the Antalya Bay in the North Levant (i.e. Turkish Mediterranean Sea) and analyzes the variations in their distribution, diversity and dominance by depth and season.

Materials and Methods

Study Area and Sampling

The western side of the Antalya Bay is characterized by rocky coasts and a steep slope with irregular non-trawlable grounds, whereas the eastern part presents sandy beaches and bottom trawling is possible on the continental shelf and most of the slope. In the study area, continental shelf (up to 200 m depth) covering a distance of 2-11 km from the shoreline. The sampling area (Figure 1), delimited by latitudes 36°28'N and 36°21'N, and longitudes 30°31'E and 31°16'E, encompasses the depth range 200 – 900 m and was divided in eight bathymetric strata (100 m interval).

After a preliminary survey made in 2009, sampling was carried out with monthly periodicity from June 2010 to June 2011, at daytime, with the R\V "*Akdeniz Su*" (overall length 26.5 m, 160 GRT, engine power 670 kW) of the Faculty of Fisheries, Akdeniz University. A standard otter-trawl in polyethylene – ground-rope 40 m, head-line 35 m, cod-end stretch mesh opening 44 mm, equipped with a polyamide cover cod-end (stretch mesh opening 24 mm) – was used. Each tow usually lasted 1 hour, but several hauls of 3-4 hours' duration, similar to that of commercial trawlers, were also made to investigate the selectivity of the gear. Catches were sorted on the deck, crustaceans, fishes and cephalopods were sorted by species, counted and weighed; doubtful species were preserved for subsequent identification in the laboratory. Size frequency distributions were recorded on the main commercial species and subsamples were immediately frozen and brought back to the laboratory for subsequent biological studies.

For each haul, decapod crustaceans were sorted by species and, species abundance (n) and species biomass (kg) data were noted.

Data Analysis

The parameters number and weight of the species for swept area (km^{-2}), the species abundance (D, number of individuals/km^{-2}) and species biomass (BI, kg/km^{-2}) indices were standardized using the software AdriaMed Trawl Information System (ATrIS; Gramolini, Mannini, Milone, & Zeuli,, 2005) for each haul. The swept area was calculated according to the wing spread of net (17.5 m) and start-end points algorithm in ATrIS. Occurrence (as the frequency of appearance of the species in the hauls) and bathymetric ranges were recorded for each species.

Following the feeding studies carried out in the Mediterranean decapods (Soto, 1985; Hopkins, Flock, Gartner, & Torres, 1994; Cartes *et al*., 2002; Cartes, Huguet, Parra, & Sanchez, 2007; Kapiris, Thessalou-

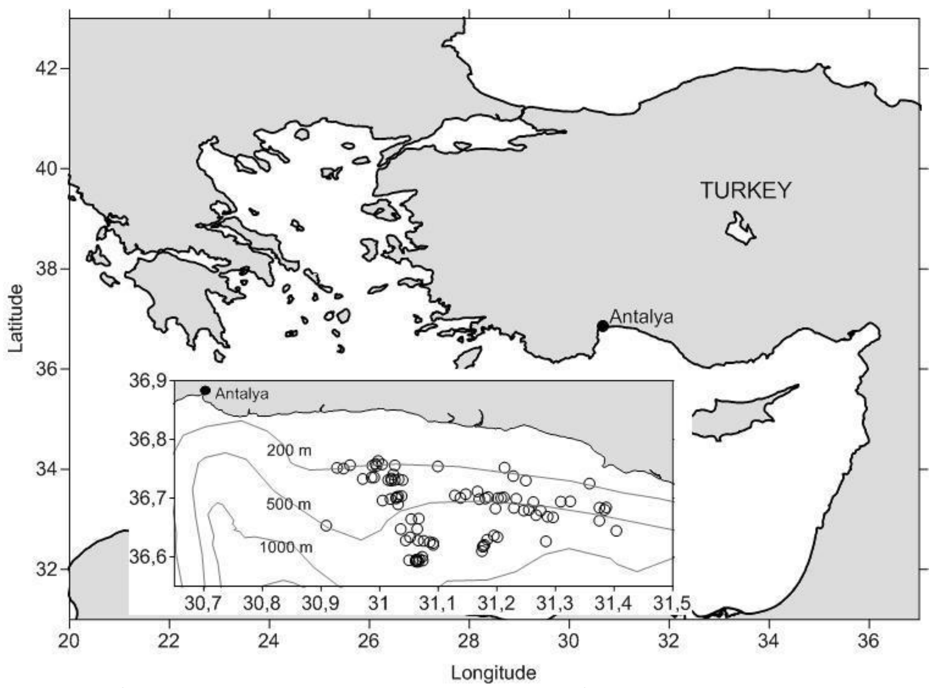

Figure 1. Bathymetry map of the studied area in the Antalya Bay. The positions of the hauls realized between 200 and 990 depth interval for the survey.

Legaki, Petrakis, & Conides, 2010; Fanelli, Papiol, Cartes, Rumolo, & López-Pérez, 2013), decapods species studied were classified within the feeding guilds: migrator macroplanton-feeders (mM), non-migrator macroplanton-feeders (nmM), large detritus-scavengers (Sca), infauna-feders (Inf), deposit-feders (Dep) and epibenthos-feder (Epip). Regarding their relative location in the water column, decapods crustaceans were classified as mesopelagic species (M), nektobenthic species (N) and benthic species (B) on the basis of their relative location in the water column (Cartes, 1998; Maynou & Cartes, 2000; Follesa *et al*., 2009).

The measures of species diversity, such as total species (S), species richness (d), Shannon-Wiener index (H') and Pielou's evenness (J') were calculated, and patterns of distribution were analysed for depth strata and seasons. Significant tendency in diversity indices by the depth stratum and season were tested using a non-parametric correlation (Spearman) analysis.

Decapod crustacean assemblages in bathyal grounds were compared using univariate and multivariate techniques. Univariate techniques were performed using SPSS version 17.0 (SPSS, 2008). The null hypothesis of no difference in abundance and in biomass between stratums and seasons was tested with the 2-factor analysis of variance (ANOVA). Prior to ANOVA analysis, the data were square root transformed and the assumption of the homogeneity of variance was tested by Levene's test.

Abundance index data of decapods obtained during the study were transformed using square root transformation in a matrix according to hauls. For all multivariate analysis, uncommon species that were seldom present (species with a density below than 0.05% and an occurrence lower than 5%) and hauls that were low abundance levels (≤ two species per haul) exhibited were not included in the data matrix, in order to reduce the variability due to higher presence of zeros (The data matrix was treated as a table defined by the sampling date, with the 71 hauls as rows and 15 species as columns. To detect spatial and temporal patterns of decapods assemblages in the investigated area, a cluster analysis was performed using the Bray-Curtis similarity index and group linkage was used (Bray & Curtis, 1957). Non-metric multidimensional scaling (nMDS) ordination, based on a Bray-Curtis similarity matrix (hauls *vs* strata) was performed using PRIMER 6 & PERMANOVA$^+$ software (Clarke & Gorley, 2006). Distance based PERMANOVA (PERmutational Multivariate ANalaysis of Variance) was used the null hypothesis of no difference in assemblage structure between deep stratums and between seasons nested within stratums. The factor stratum was analyzed as a fixed factor with eight levels (200 to 900 m), while the factor season was analyzed as a random factor with four levels nested in each stratum.

Two-way SIMPER analyses (Similarity percentage analysis) were performed in order to identify species contributions in abundance using the same procedure as in cluster analysis. The typifying species were selected using SIMPFER procedure which identifies the species contributing most to intra-stratum similarities. A cut-off criterion was applied to allow identifying a subset of species whose cumulative percentage contribution to the observed value of similarity reached 90%. Differences in multivariate dispersion between the assemblages in the hauls of four seasons and eight stratums were tested by PERMDISP (Distance-based test for homogeneity of multivariate dispersions) (Cartes, Maynou, Fanelli, Papiol, & Lloris, 2009).

Results

Species Composition and Diversity

A total of 63 796 individuals belonging to 34 species of decapod crustaceans and 20 families was collected over the 87 hauls, having a total duration of 121 hours and covering a total sampling area of 9.565 km^{-2}. Table 1 shows the taxonomic list of the species, regarding their bio-ecological categories and feeding guilds. Table 2 summarizes the bathymetric range of occurrence of each species. The most important infraorder in term of species richness (12 species) were Caridea, followed by the Brachyura (11 species), Dendrobranchiata (6), and Anomura (4). Only one species of Achelata was found.

The number of decapod species (S) and average values of diversity indices by stratum and by season are reported in Table 3. The two-way ANOVA shoved that the stratum had significant effect on the species number and all three diversity indices (*d*, *J'* and *H'*), while the season had a significant effect on indexes, except *J'* value (Table 4). The highest number of decapods species (19) and the greatest richness (1.942) were found on 300 m of depth. Spearman's nonparametric correlation analysis (Table 5) shows that the *S* (P<0.01) had a strongly negative correlation with stratum, while the *J'* vs stratum had a positive correlation (P<0.05). There was no significant correlation among season and index values (Table 5).

Abundance and Biomass

The mean values (± sd) of D and BI indices calculated by single and pooled strata, and seasons, obtained for all decapod crustaceans caught during surveys, are given in Table 6. In three hauls (200, 300 and 400 m in October) during the surveys, there were no crustacean specimens. Excluding these three hauls, D value fluctuated between 26 and ~20 000 n/km^{-2} (mean= 5600 ±5458) while the majority of them (66.7%) ranged less than 5000 n/km^{-2}. The highest mean abundance was found almost equal for three stratums (300-500 m). The highest mean BI value

Table 1. List of decapod crustaceans collected in the bathyal ground off Antalya Bay with Bio-ecological categories (M: mesopelagic; N: nektobenthic; B: benthic) and feeding guilds (mM: migrator macroplancton feeder; nmM: non-migrator macroplancton feeder; Sca: large detritus-scavengers; Inf: infaunal feeder; Dep:deposit feeder; Eepip:epibenthos feeder; n.a.; not available) ([1]:Soto,1985; [2]: Hopkins et al.,1994; [3]: Cartes et al.,2002; [4]: Cartes et al.,2007;[5]: Kapiris et al.,2010; [6]: Fanelli et al.,2013).

Infraorder	Family	Species	Bio-ecological categories[3,4]	Feeding Guilds[1,2,3,4,5,6,]
Dendrobranchiata	Aristeidae	*Aristaemorpha foliacea* (Risso, 1827)	N	Inf
		Aristeus antennatus (Risso, 1816)	N	Inf
	Penaeidae	*Funchalia villosa* (Bouvier, 1905)	N	mM
		Parapenaeus longirostris (Lucas, 1846)	N	Inf
	Sergestidae	*Sergestes arachnipodus* (Cocco, 1832)	M	mM
		Sergia robusta (S.I. Smith, 1882)	M	mM
Caridea	Alpheidae	*Alpheus glaber* (Olivi, 1792)	B	Dep
	Oplophoridae	*Acanthephyra eximia* (S.I. Smith, 1884)	N	nmM
		Acanthephyra pelagica (Risso, 1816)	M	mM
	Pandalidae	*Chlorotocus crassicornis* (A.Costa, 1871)	N	Inf
		Plesionika acanthonotus (S.I. Smith, 1882)	N	nmM
		Plesionika antigai (Zariquiey Álvarez, 1955)	N	nmM
		Plesionika edwardsii (Brandt, 1851)	N	nmM
		Plesionika heterocarpus (A.Costa, 1871)	N	nmM
		Plesionika martia (A. Milne-Edwards, 1883)	N	nmM
		Plesionika narval (Fabricius, 1787)	N	nmM
	Pasiphaeida	*Pasiphaea multidentata* (Esmark, 1866)	M	mM
		Pasiphaea sivado (Risso, 1816)	M	mM
Achelata	Polychelidae	*Polycheles typhlops* (Heller, 1862)	B	Epip
Anomura	Diogenidae	*Dardanus arassor* (Herbst, 1796)	B	Sca
	Paguridae	*Pagurus alatus* (Fabricus, 1775)	B	Sca
		Pagurus excavatus (Herbst, 1791)	B	Sca
		Pagurus prideaux (Leach, 1815)	B	Sca
Brachyura	Calappidae	*Calappa granulata* (Linnaeus, 1758)	B	Inf
	Dorippidae	*Medorippe lanata* (Linnaeus, 1767)	B	Inf
	Geryonidae	*Geryon longipes* (A. Milne-Edwards, 1882)	B	Inf
	Goneplacidae	*Goneplax rhomboides* (Linnaeus, 1758)	B	Inf
	Homolidae	*Homola barbata* (Fabricius, 1793)	B	Inf
	Latreilliidae	*Latreillia elegans* (Roux, 1830)	B	n.a.
	Majidae	*Nemaja goltziana* (d'Oliveria, 1888)	B	n.a.
	Parthenopidae	*Spinolambrus macrochelos* (Herbst, 1790)	N	n.a.
	Portunidae	*Liocarcinus depurator* (Linnaeus, 1758)	B	Epip
		Bathynectes maravigna (Prestandrea, 1839)	B	Epip
	Xanthidae	*Monodaeus couchii* (Couch, 1851)	B	Inf

(117 kg/km^{-2}) was recorded at 500 m stratum, and BI value by hauls fluctuated between 0.20 and 244 kg/km^{-2} (mean=60.1±62), while almost all samples (80%) were less than 100 kg/km^{-2}. All the above mentioned indices in the frame of the survey presented the maximum values in summer.

The temporal and spatial patterns of change in D and BI values were not similar. A high significant effect of depth stratum on the D and BI values was found (P<0.001). However, season and interaction of season *x* depth shown insignificantly effects on both indices. The test of homogeneity of variance null hypothesis for both abundance (Levene: 0.740; P>0.05) and biomass (Levene: 0.654; P>0.05) were equal across groups. The used post-hoc test (Tamhane's T2) gave a high significant difference comparing the abundance and biomass among depth stratums (Table 5).

A statistical significant strongly negative trend was observed between depth and D indices (r = -0.505; P<0.01) (Table 5, Figure 2a), while slightly negative trend between depth and BI was not found statistically significant (r =-0.171, P>0.05) (Table 5, Figure 2b). With seasons, neither D (r=-0.188; P>0.05) nor BI (r = -0.210; P>0.05) indices were not detected a statistically significant correlation.

Spatial Structure of the Decapod Assemblages

The cluster analysis among 71 hauls showed that two main groups can be clearly defined along the bathymetrical strata, the first one at depth of shallower than 500 m (upper slope) and the other one includes the hauls carried out in depths more than ≥500 m (middle slope) (Figure3). The left branching (middle slope) of the similarity can be further sub-divided with clearly sub-groups between stratums, which join respectively deeper hauls between 700-999 m (13 hauls) and between 500-699 m (30 hauls). Identified two main assemblages were also separated

Table 2. Occurrence (%) in hauls, abundance (D, ind/km^{-2}) in each depth stratum, total abundance and biomass (BI, kg/km^{-2}) and bathymetric distribution of decapod crustaceans collected in the bathyal ground off Antalya Bay.(*: The mean D and BI values. The absent values correspond to the species which were <1 n/km^{-2})

Species	Ocurence (%)	Σn	Mean*		D value in depth stratum							
			D (n/km^{-2})	BI(kg/km^{-2})	200	300	400	500	600	700	800	900
Aristaeomorpha foliacea	60.9	15337	1145	20.0	-	-	783	3991	3442	608	279	59
Aristeus antennatus	47.1	2615	247	3.85	-	-	50	694	455	398	223	152
*Funchalia villosa**	1.1	1	-	-	-	-	-	-	0.6	-	-	-
Parapenaeus longirostris	60.9	23219	2393	14.2	3864	9765	5085	419	3.9	5.2	-	-
Deosergestes arachnipodus	13.8	76	5.7	0.02	-	-	1.7	14	23	7	-	-
Sergia robusta	17.2	132	103	0.14	-	-	-	1.7	18	33	6	762
*Alpheus glaber**	1.1	2	-	-	1.8	-	-	-	-	-	-	-
*Acanthephyra eximia**	1.1	1	-	-	-	-	-	-	-	-	1.9	-
Acanthephyra pelagica	4.6	10	6.6	0.01	-	-	-	-	2.8	3.1	-	47
*Chlorotocus crassicornis**	3.4	5	-	-	3.5	1	-	-	-	-	-	-
Plesionika acanthonotus	17.2	92	7.4	0.02	7.1	1.9	0.4	22	22	6.3	-	-
*Plesionika antigai**	1.1	4	-	-	-	-	-	2.2	-	-	-	-
Plesionika edwardsii	23.0	5431	356	2.96	-	753	1931	141	15	7	-	-
Plesionika heterocarpus	35.6	4487	385	0.67	49	1724	895	412	-	1	-	-
Plesionika martia	36.8	11048	721	3.52	-	-	1565	3960	224	17	-	-
Plesionika narval	3.4	707	78	0.24	621	2.9	-	-	-	-	-	-
Pasiphaea multidentata	4.6	6	4.7	0.01	0.9	-	-	-	0.6	1	-	35
Pasiphaea sivado	4.6	6	-	-	-	-	-	2.8	-	1	-	-
Polycheles typhlops	54.0	249	28	0.45	-	3.9	18	48	62	28	27	35
*Dardanus arassor**	2.3	3	-	-	-	1	0.5	-	-	-	-	-
*Pagurus alatus**	1.1	1	-	-	-	-	-		0.6	-	-	-
*Pagurus excavatus**	1.1	1	-	-	0.9	-	-	-	-	-	-	-
Pagurus prideauxi	6.9	83	7.9	0.02	49	3.4	9.7	1.1	-	-	-	-
Calappa granulata	29.9	57	5.5	0.30	22	9.7	5.3	6.6	-	-	-	-
Medorippe lanata	10.3	26	2.9	0.11	21	2	0.4	-	-	-	-	-
Geryon longipes	8.1	8	2.6	0.01	0.9	1.0	-	-	1	-	5.9	12
*Goneplax rhomboides**	3.4	3	-	-	0.9	1.0	0.4	-	-	-	-	-
*Homola barbata**	1.1	2	-	-	-	1.9	-	-	-	-	-	-
Latreillia elegans	6.9	52	5.9	0.01	34	13	-	-	-	-	-	-
Nemaya goltziana	8.1	7	-	-	4.4	1.9	-	-	-	-	-	-
Spinolambrus macrochelos	35.6	100	8.9	0.09	27	7.8	18	12	1.7	5.2	-	-
*Liocarcinus depurator**	1.1	1	-	-	-	1	-	-	-	-	-	-
Bathynectes maravigna	11.5	13	1.1	0.01	0.9	1.0	0.4	-	4.5	2.1	-	-
Monodaeus couchii	3.4	11	1.1	0.03	7.1	-	0.4	-	1.1	-	-	-

Table 3. Decapods assemblage structure on the whole study area (200-900 m) per season and per depth stratums. (*S*: total species; *d*: species richness; *H'*: diversity; *J'*: evenness)

	Depth stratum (m)								Season			
	200	300	400	500	600	700	800	900	Autumn	Spring	Summer	Winter
S	16	19	18	18	16	13	6	7	19	26	21	20
d	1.694	1.942	1.854	1.840	1.760	1.703	0.636	0.855	2.085	2.847	2.169	2.281
H'	0.598	0.746	1.277	1.361	0.906	1.126	0.898	1.108	1.531	1.613	1.275	1.917
J'	0.216	0.253	0.442	0.471	0.327	0.439	0.558	0.569	0.520	0.495	0.419	0.640

in nMDS analysis according to depth. The assemblage of upper slope was separated as independent groups presenting a similar community structure (Figure 4). PERMANOVA test showed a significant difference in assemblages structure between depth stratum, while the test did not show any significant effect of seasonality and interaction of season *x* depth (Table 7).

PERMDISP test shows; significant differences in the homogeneity of dispersion between deep

Table 4. Results of test of between-subject effects by the 2-way ANOVA for the diversity characters. (BI=biomass index, kg/km^{-2}, D=number of individuals/km^{-2}) *P*-value significantly different at P<0.05(*) and at P<0.01(**)

Source	d.f	*S*	*d*	*J'*	*H'*	D	BI		Post-hoc test (Tamhane's T2)
Stratum	67	0.001**	0.013*	0.000**	0.013*	0.000**	0.000**	D	700 and 800 *vs* 200, 300,400,500 and 600
Season	3	0.002**	0.000**	0.226	0.017*	0.448	0.086	BI	500 *vs* 700 and 800
Strat.*x*Season	17	0.785	0.830	0.057	0.223	0.507	0.273		600 *vs* 800

Table 5. Calculated p-values from Spearman's correlation analysis for the faunistic characters. Bold numbers show that significantly correlated at P<0.05.

		D	BI	*S*	*d*	*J'*	*H'*
Stratum	*r*	-0.499	-0.167	-0.783	-0.619	0.810	0.310
	p-value	0.000	0.129	0.022	0.102	0.015	0.456
Season	r	-0.040	-0.126	0.200	0.400	0.200	0.400
	p-value	0.715	0.253	0.800	0.600	0.800	0.600

Table 6. Mean abundance (D, n/km^{-2}) and biomass (BI, kg/km^{-2}) indices with standard deviation (sd) computed by stratum and season for crustacean caught species.

Spatial				Temporal			
Stratum	Hauls	D (± sd)	BI (± sd)	Season	Hauls	D (± sd)	BI (± sd)
200	12	6 597 ± 8 567	38.5± 59.3	Summer	16	9 707 ± 8 826	79.8 ± 69.8
300	12	10 601 ± 8 852	56.7± 56.5	Autumn	19	5 612 ± 6 597	52.7 ± 48.4
400	15	10 087 ± 6 002	62.0 ± 36.1	Winter	12	4 148 ± 4 480	36.9 ± 53.1
500	14	10 315 ± 6 415	117.0 ± 81.4	Spring	16	6 512 ± 5 911	64.6 ± 67.1
600	14	5 030 ± 4 707	81.8 ± 61.6				
700	12	1 150 ± 1 231	21.6 ± 22.2				
800	7	538 ± 449	13.1 ± 12.1				
900	1	364	4.1				
	87	5600 ± 5458	60.1 ± 62.0		87	5600 ± 5458	60.1 ± 62.0

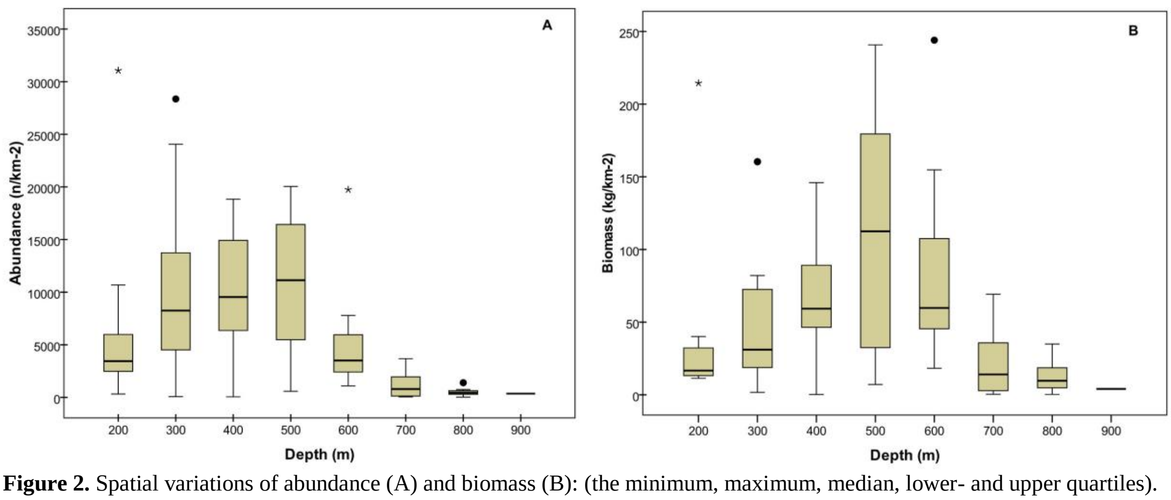

Figure 2. Spatial variations of abundance (A) and biomass (B): (the minimum, maximum, median, lower- and upper quartiles).

Table 7. Results of multivariate analysis PERMANOVA for decapods crustacean assemblages based on the Spearman's rank correlation distance (9999 permutation). (df: degree of freedom; MS: mean square; P: level of significance; ns: not significant; **: P<0.01)

Source	*df*	*MS*	*Pseudo-F*	*P*
Stratum	7	16 462.0	1.091	0.001**
Season	3	1982.2	9.038	0.370 ^{ns}
Str. * Ses.	18	1875.2	1.250	0.084 ^{ns}
Res	43	1499.7		
Total	71			

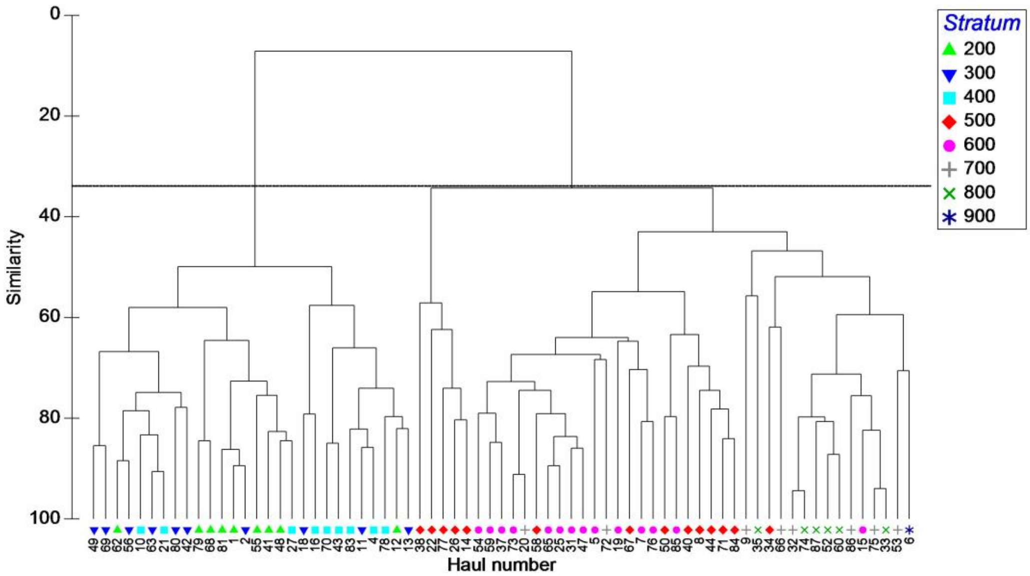

Figure 3. Cluster results of experimental hauls at eigth depth stratums in bathyal ground in Antalya Bay, eastern Mediterranean, obtained with group average clustering method and percent similarity resemblance measure on abundance of decapod crustaceans obtained. The upper line indicates groups at the 34% level of similarity.

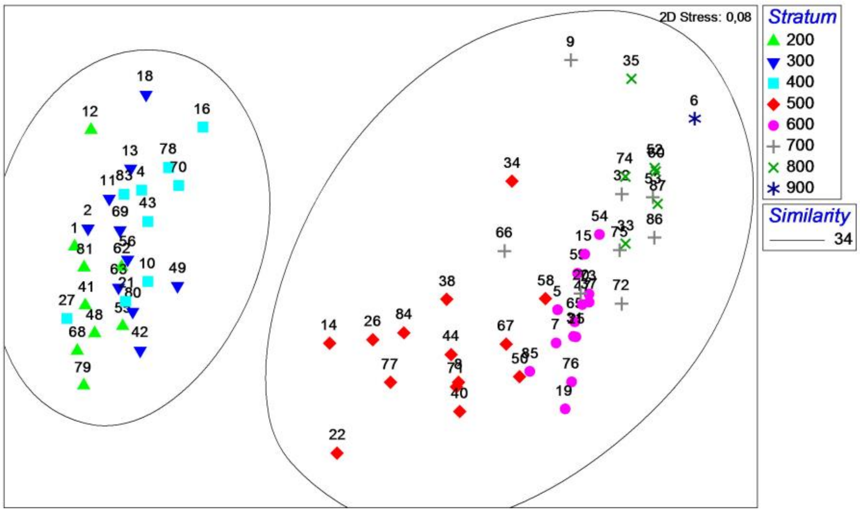

Figure 4. MDS ordination plot of abundance data of decapods crustaceans obtained by each haul during the survey.

stratums ($F=5.712$; $df_1=7$; $df_2=65$; $P<0.001$) and any significant differences between seasons ($F=1.288$; $df_1=3$; $df_2=68$; $P>0.05$).

Composition of the Decapods Assemblages

Table 8 shows the percentage contribution of the main contributor species to within group similarity calculated for each depth stratum (200-800 m) and slopes (upper and middle). *P.longirostris* and *P. heterecarpus* were the main contributor species in the upper slope (200-499 m) assemblages. Similarly, *A. foliacea* and *A. antennatus* were the most typifying species in all four depth stratums on the central slope (500-900 m) assemblages. Third important contributor species was *P. martia* in the middle slope assemblages.

Among the 34 caught decapod crustaceans, five commercial shrimp species (*P. longirostris*, *A. foliacea*, *A. antennatus*, *P. martia* and *P. edwardsii*) constitute the 86% and 96% of total abundance and biomass, respectively. In terms of total abundance, the predominant species were *P. longirostris* (37.7%), *A. foliacea* (22.1%) and *P. martia* (14.2%). In terms of biomass, *A. foliacea* (44.3%), *P. longirostris* (28.6%) and *A. antennatus* (8.7%) (Figure 5). The commercial catch on the upper slope was characterized by deep-water pink shrimp *P. longirostris*, with an average abundance of 6 483 n/km^{-2}, with maximum of 30 830 n/km^{-2} in the 200 m stratum. On the middle slope (500–900 m) the commercial catch was dominated by the red shrimps – *A. foliacea* and *A. antennatus* – with the first outnumbering the second by 4.6:1. The average abundance of *A. foliacea* was 2735 n/km^{-2},

Table 8. Results of two-factor SIMPER analyses based on Bray-Curtis similarity (Cut-off at 85% MA: mean abundance, MS: mean similarity; %MS: percentage contribution to the similarity; Not present any results for 900 m, because only one haul was on strata)

a)Factor: stratum				b)Factor: slope			
Species	MA	% MS	Σ %MS	Species	MA	% MS	Σ %MS
200 m							
Av.Sim:65.4							
P. longirostris	71.7	86.4	86.4				
300 m							
Av.Sim:59.0							
P. longirostris	83.6	73.4	73.4				
P.heterocarpus	35.4	24.0	97.4				
400 m				Upper slope assemblage (200-499 m)			
Av.Sim:60.8				Av.Sim:58.1			
P. longirostris	93.0	71.8	71.8	*P. longirostris*	82.8	81.6	81.6
P. heterocarpus	31.5	19.7	91.5	*P. heterocarpus*	23.8	11.9	93.5
500 m				Middle slope assemblage (500-899 m)			
Av.Sim:53.0				Av.Sim:49.0			
A. foliacea	65.3	45.4	45.4	*A. foliacea*	47.3	53.5	53.1
P.martia	49.9	27.0	72.5	*A. antennatus*	19.4	21.9	75.5
P.longirostris	18.5	8.9	81.4	*P. martia*	21.5	10.	85.5
P. typhlops	7.0	5.6	87.0				
600 m							
Av.Sim:70.1							
A. foliacea	56.7	56.8	56.8				
A. antennatus	19.8	19.0	75.8				
P. martia	14.6	14.5	90.4				
700 m							
Av.Sim:56.6							
A. foliacea	27.3	44.1	44.1				
A. antennatus	21.9	34.8	86.1				
800 m							
Av.Sim:72.4							
A. foliacea	16.7	44.1	44.1				
A. antennatus	15.1	38.5	82.6				

with maximum of 11 588 n/km^{-2} in the 600 meters stratum.

Bio-Ecologiacal Categories and Feeding Guilds

In term of bio-ecological categories (Table 9), the crustaceans assemblage were greatly dominated by nektobenthic (*N*) species (10 species accounting for 99.2% of total abundance) on the upper slope and on the middle slope (11 species accounting for 92.9% of total abundance). On the upper slope, the benthic (*B*) species were largely represented by 15 species, but these species accounting for only 0.79% of the total abundance.

The composition of feeding guilds for crustacean sampled also shown in Table 9. On the upper slope, crustacean assemblages were dominated by infaunal feeders (37%) and by non-migrator macroplanton feeders (18.5%), both groups accumulating 99.3% of abundance. *P. longirostris* was the dominant species among infaunal feeders, while *P. heterocarpus* dominated among nmM.

On the middle slope, the three feeding guilds (non-migrator macroplanton feeders, migrator macroplanton feeders and infaunal feeders) presented equal number of species (26.1%), dominated accumulating 98.6% of abundance. Five infaunal feeders' species accounting for 64.1% of the total abundance in the middle slope. *A. foliacea* was dominant species among infaunal feeders, while *P. martia* dominated among nmM.

Discussions

The bathyal decapod crustaceans represent a very dominant faunal component in the benthic communities of the Mediterranean Sea (Abelló, Valladares, & Castellón, 1988; Cartes & Sardà, 1992; Sardà *et al*., 1994; Maynou & Cartes, 2000; Company *et al*., 2004) and are linking the lower and the higher trophic levels (Wenner & Boesch, 1979; Cartes, 1998).

Several studies have revealed the natural gradient structuring assemblages of megafauna (Cartes & Sardà, 1992; Colloca, Cardinale, Belluscio, & Ardizzone, 2003; Papiol, Cartes, Fanelli, & Rumolo, 2013). Also, temporal changes in bathyal assemblage composition have been studied and

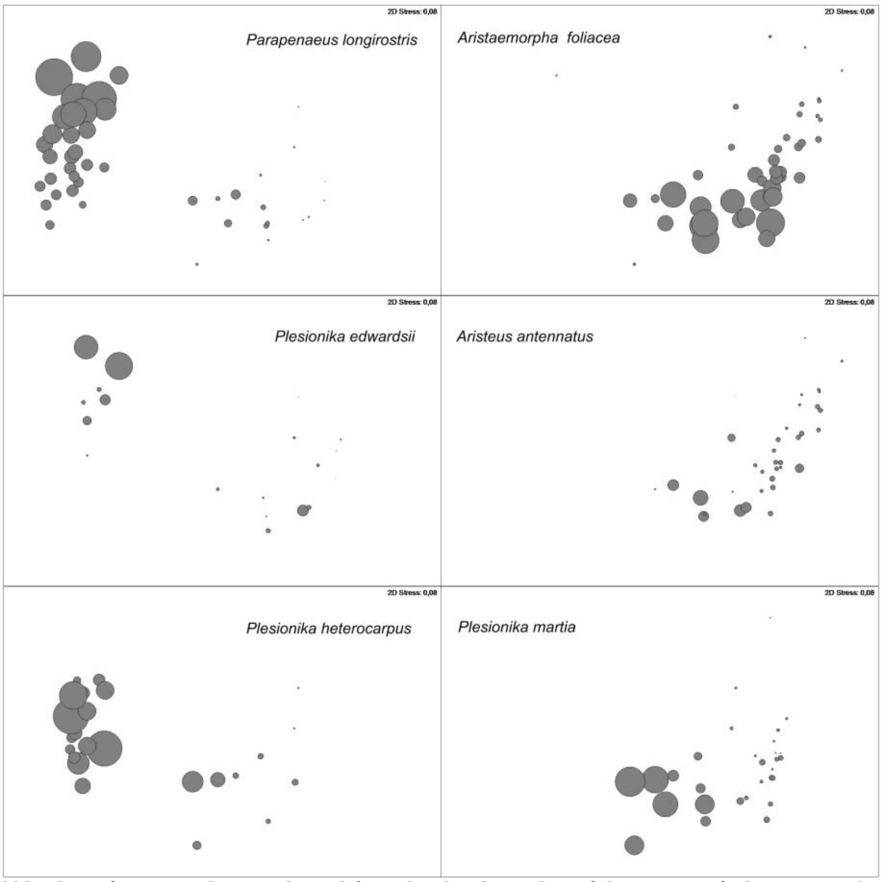

Figure 5. The bubble plots of nMDS ordination derived from the abundance data of the most typified six species between stratums in upper and middle slopes. Circle diameter is proportional to the abundance. The largest circle corresponds to the maximum abundance (31 000 n/km^{-2}) of each species.

Table 9. Distribution of decapod crustaceans collected in the bathyal ground off Antalya Bay according the Bio-ecological categories (M:mesopelagic, N:nektobenthic, B:benthic) and feeding guilds (mM: migrator macroplanton feeder; nmM:non-migrator macroplanton feeder; Sca:large detritus-scavengers; Inf:infaunal feeder; Dep:deposit feeder; Epip:epibenthos feeder; n.a.:not available)

		Upper slope n=27		Middle slope n=22	
		D (n/km^{-2})	% of species	D (n/km^{-2})	% of species
Bio-ecological categories	N	905.2	37.0	283.6	47.8
	B	4.9	55.6	6.8	30.4
	M	0.4	7.4	40.0	21.7
Feding guilds	Inf	654.2	37.0	358.5	26.1
	nmM	503.4	18.5	161.6	26.1
	Sca	7.2	11.1	0.4	8.7
	Epip	2.8	11.1	20.7	8.7
	n.a.	11.8	11.1	3.8	4.3
	Dep:	0.6	3.7	-	-
	mM	0.4	7.4	33.4	26.1

season has been found to affect significantly the structure of megafaunal assemblages (Maynou & Cartes 2000; Madurell, Cartes, & Labropoulou, 2004; Moranta *et al*., 2008). In the presented study, it was determined that no effect of the temporal change in assemblage, while the gradient was dictated an effective factor in the structure of decapods crustacean assemblage in the bathyal ground of the Antalya Bay. Generally speaking, according to the results of the present study and the previous ones, the comparison of the spatiotemporal variation of the bathyal decapods crustacean assemblages among the various Mediterranean areas did not confirm various differences between the western, central and eastern part of the Mediterranean. All the observed differences could be attributed to the different environmental variations, the oligotrophic characters of the central and, mainly, eastern part of the basin and, obviously, to the different fishery status in these species.

The community structure of the bathyal decapod crustaceans found in the study area was composed of 34 species belonging to 20 families. Including the results from the present study, the number of known decapods from the Antalya Bay has now reached 72 species. Recently the occurrence of the alien species *Sicyonia lancifer* has been reported in the same area (Patania & Mutlu, 2015). In a previous study on the bathyal trawling grounds in the Gulf of Antalya the captures of 12 decapods new or rare species have been recorded (Deval & Froglia, 2016). Among them four species (*Funchalia villosa, Plesionika acanthonotus, P. gigliolii, Monodaeus couchii*) are recorded for the first time in the Levant Sea while the total number of decapods caught in the Turkish Mediterranean area is 265 (Deval & Froglia, 2016).

The bathyal decapod crustacean community of the Antalya Bay's deep-waters (Eastern Mediterranean) presented a clear zonation effect, with a series of well-defined bathymetric boundaries that seemed to be connected to depth-related factors. A decline in the number of decapod species, their abundance and biomass with depth was evident in the Antalya Bay. This pattern was observed also in the western (Cartes & Sardà, 1992; Cartes, 1993) and central Mediterranean (Politou, Maiorano, D'Onghia, & Mytilineou, 2005). The highest abundance in the middle slope was mainly due to the species *A. foliacea*, which consist a target fishery trawlable species in the study area (Deval *et al*., 2009; Deval & Kapiris, 2016). Taking into consideration the relatively stable environmental conditions in these depths and the high oligotrophy of the area (Stergiou, Christou Georgopoulos, Zenetos, & Souvermezoglou, 1997), the main factor determining this reduction with depth could be the low trophic resource availability. The above mentioned relative consistent environmental conditions in the bathyal groups could explain the fact that does not change the abundance and biomass of decapods in the study area on small temporal scales (1 season). Although comparison of abundance with other studies is difficult, because of the different types of gear and methods used, the general decapod crustacean fauna distribution is quite similar to that found in other Mediterranean areas (Abelló *et al*., 1988; Cartes & Sardà, 1992; Cartes, Sorbe, & Sardà, 1994; Ungaro *et al*., 1999; Abelló, Carbonell, & Torres, 2002; Maynou & Cartes, 2000; Follesa *et al*., 2009). Other environmental parameter which affects the changes observed in the decapod assemblages on Le Danois Bank (Spain) is the nature of the substrate (Cartes *et al*., 2007).

Two main decapods assemblages were detected along the bathyal ground: one on the shelf break/upper slope characterized by *P. longirostris* and *P. heterocarpus* and another on the middle slope with *A. foliacea, A. antennatus* and *P. martia*. *P. longirostris.* The comparison of the abundance of the decapods found in the present study with previous ones could be considered as difficult, due to the different types of gear and methods used, the general fauna distribution is quite similar to that found in other Mediterranean areas (Cartes *et al*., 1994; Ungaro *et al*., 1999; Abelló *et al*., 2002; Politou *et al*., 2005). The two commercial deep-water shrimps *A. foliacea* and *A. antennatus* were also frequent in the Greek Aegean and in the Ionian Seas consisting the most common deep-water decapods (Kapiris, Thessalou-Legaki, and Moraitou-Apostolopoulou, 2000; Papakonstantinou & Kapiris, 2001; 2003; Politou *et al*., 2005). Kapiris, Dogrammatzi, Christidis, Maina, & Klaoudatos (2014) present only 7 species in the 500-600 m of the Central Aegean, while in the 500-700 m of the E. Ionian Sea 27 species have been recognized by Politou *et al*. (2005). *A. foliacea* and *P. martia* were the most abundant species and the CPUE values of *A. foliacea* ranged between 0.70-2.5 kg/h^{-1} (Kapiris *et al*., 2014). In contrast to this, the abundance of *A. foliacea* is very lower to the western part of the Mediterranean and this could be explained to the overfishery exerted and the fishing pressure exercised in the deep waters of the westernmost areas (Orsi Relini & Relini, 1985; Matarrese, D'Onghia, Tursi, & Maiorano, 1997) In addition to this, different hydrological conditions (i.e. salinity and temperature) between areas are factors which affect the distribution of the species along the Mediterranean (Relini & Orsi Relini, 1987; Murenu, Cuccu, Follesa, Sabatini, & Cau, 1994). Most of the decapod species found in the present study, with only some exceptions were also found in the SE Adriatic Sea, which is adjacent to the E. Ionian (Vaso & Gjiknuri, 1993; Ungaro *et al*., 1999). In the W. Mediterranean 28 species consist the bathyal decapods fauna were identified and the most pronounced qualitative changes in the fauna were recorded between 1000 and 1200 m and at around 2000 m (Cartes, 1993). In the Eastern Ionian Sea 39 decapod species have been reported between 300-900 m of depth (Politou *et al*., 2005).

According to the bio-ecological category and their feeding guilds, the bathyal decapods found in the upper slope of the Antalya Bay are nektobenthic and infaunal and non-migrator feeders species, like *P. longirostris, P. martia, P. heterocarpus* and *P. edwardsii*. In the middle slope a prevalence of nektobenthic and mesopelagic species has been observed consuming infaunal, epibenthos and non-migrator macroplanton preys, like *A. foliacea, A. antennatus, P. martia, P. heterocarpus. P. typhlops* and *S. robusta*. A similar distribution of feeders in these depth zones have been identified in the central Mediteranean (Follesa *et al*., 2009) and off the South-West Balearic Islands (Western Mediterranean)

(Maynou & Cartes, 2000). These differences could be attributed to the available food availability, the local geographic conditions which affect the species distribution and the vertical fluxes of organic carbon to the sea floor (Danovaro, Dinet, Duineveld, & Tselepides,1999).

In conclusion, the present study provides valuable information concerning the composition, depth distribution, structure of bathyal decapod crustaceans in the eastern Mediterranean and points out the similarities and dissimilarities between the western and central part of the basin. In addition, improves the knowledge concerning the benthic deep waters decapods fauna in the whole Mediterranean Sea.

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