



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

Mehmet C. Deval^{1,*}, Serpil Yılmaz¹, Kostas Kapiris²

¹ Akdeniz University, Dumlupınar Bulvarı 07058 Kampüs, Antalya, Turkey.

² Hellenic Centre for Marine Research, Institute of Marine Biological Resources, Agios Kosmas, Hellinikon, 16604 Athens, Greece.

* Corresponding Author: Tel.: +90.242 2262012; Fax: +90.242 2262013;
E-mail: deval@akdeniz.edu.tr

Received 19 June 2016
Accepted 22 March 2017

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 *Aristaeomorpha foliacea*, *Aristeus antennatus*, *Parapenaeus longirostris* and two pandalid shrimps *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-

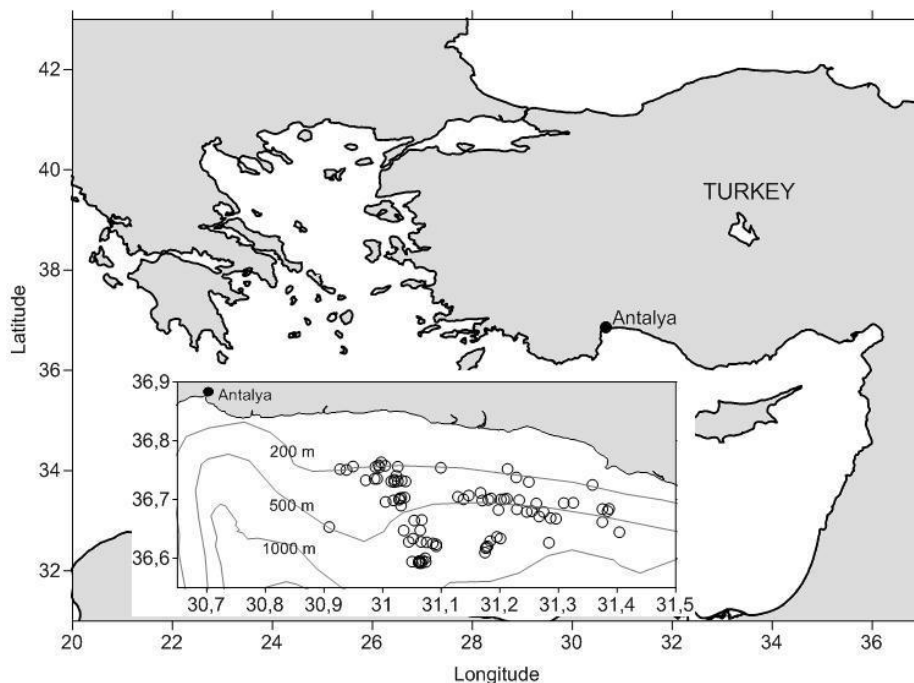


Figure 1. Bathymetry map of the studied area in the Antalya Bay. The positions of the hauls realized between 200 and 990 depth interval for the survey.

Legaki, Petrakis, & Conides, 2010; Fanelli, Papiol, Cartes, Rumolo, & López-Pérez, 2013), decapods species studied were classified within the feeding guilds: migrator macroplankton-feeders (mM), non-migrator macroplankton-feeders (nmM), large detritus-scavengers (Sca), infauna-feeders (Inf), deposit-feeders (Dep) and epibenthos-feeder (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 strata 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 (\leq 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 ANalysis Of Variance) was used the null hypothesis of no difference in assemblage structure between deep strata and between seasons nested within strata. 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 strata 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 km². 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 showed 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 (\pm 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/km² (mean= 5600 \pm 5458) while the majority of them (66.7%) ranged less than 5000 n/km². The highest mean abundance was found almost equal for three strata (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 macroplankton feeder; nmM: non-migrator macroplankton 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	<i>Aristaemorpha foliacea</i> (Risso, 1827)	N	Inf
		<i>Aristeus antennatus</i> (Risso, 1816)	N	Inf
	Penaeeidae	<i>Funchalia villosa</i> (Bouvier, 1905)	N	mM
		<i>Parapenaeus longirostris</i> (Lucas, 1846)	N	Inf
Caridea	Sergestidae	<i>Sergestes arachnipodus</i> (Cocco, 1832)	M	mM
		<i>Sergia robusta</i> (S.I. Smith, 1882)	M	mM
	Alpheidae	<i>Alpheus glaber</i> (Olivi, 1792)	B	Dep
		Oplophoridae	<i>AcanthePHYRA eximia</i> (S.I. Smith, 1884)	N
	<i>AcanthePHYRA pelagica</i> (Risso, 1816)		M	mM
	Pandalidae	<i>Chlorotocus crassicornis</i> (A.Costa, 1871)	N	Inf
		<i>Plesionika acanthonotus</i> (S.I. Smith, 1882)	N	nmM
		<i>Plesionika antigai</i> (Zariquiey Álvarez, 1955)	N	nmM
		<i>Plesionika edwardsii</i> (Brandt, 1851)	N	nmM
		<i>Plesionika heterocarpus</i> (A.Costa, 1871)	N	nmM
		<i>Plesionika martia</i> (A. Milne-Edwards, 1883)	N	nmM
		<i>Plesionika narval</i> (Fabricius, 1787)	N	nmM
	Pasiphaeida	<i>Pasiphaea multidentata</i> (Esmark, 1866)	M	mM
<i>Pasiphaea sivado</i> (Risso, 1816)		M	mM	
Achelata	Polychelidae	<i>Polycheles typhlops</i> (Heller, 1862)	B	Epip
Anomura	Diogenidae	<i>Dardanus arassor</i> (Herbst, 1796)	B	Sca
	Paguridae	<i>Pagurus alatus</i> (Fabricius, 1775)	B	Sca
		<i>Pagurus excavatus</i> (Herbst, 1791)	B	Sca
Brachyura	Calappidae	<i>Calappa granulata</i> (Linnaeus, 1758)	B	Inf
		<i>Medorippe lanata</i> (Linnaeus, 1767)	B	Inf
	Geryonidae	<i>Geryon longipes</i> (A. Milne-Edwards, 1882)	B	Inf
	Goneplacidae	<i>Goneplax rhomboides</i> (Linnaeus, 1758)	B	Inf
	Homolidae	<i>Homola barbata</i> (Fabricius, 1793)	B	Inf
	Latreilliidae	<i>Latreillia elegans</i> (Roux, 1830)	B	n.a.
	Majidae	<i>Nemaja goltziana</i> (d'Oliveria, 1888)	B	n.a.
	Parthenopidae	<i>Spinolambus macrochelos</i> (Herbst, 1790)	N	n.a.
	Portunidae	<i>Liocarcinus depurator</i> (Linnaeus, 1758)	B	Epip
		<i>Bathynectes maravigna</i> (Prestandrea, 1839)	B	Epip
	Xanthidae	<i>Monodaeus couchii</i> (Couch, 1851)	B	Inf

(117 kg/km²) was recorded at 500 m stratum, and BI value by hauls fluctuated between 0.20 and 244 kg/km² (mean=60.1±62), while almost all samples (80%) were less than 100 kg/km². 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 stratum (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 subdivided with clearly sub-groups between stratum, 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/km²) in each depth stratum, total abundance and biomass (BI, kg/km²) 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/km²)

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

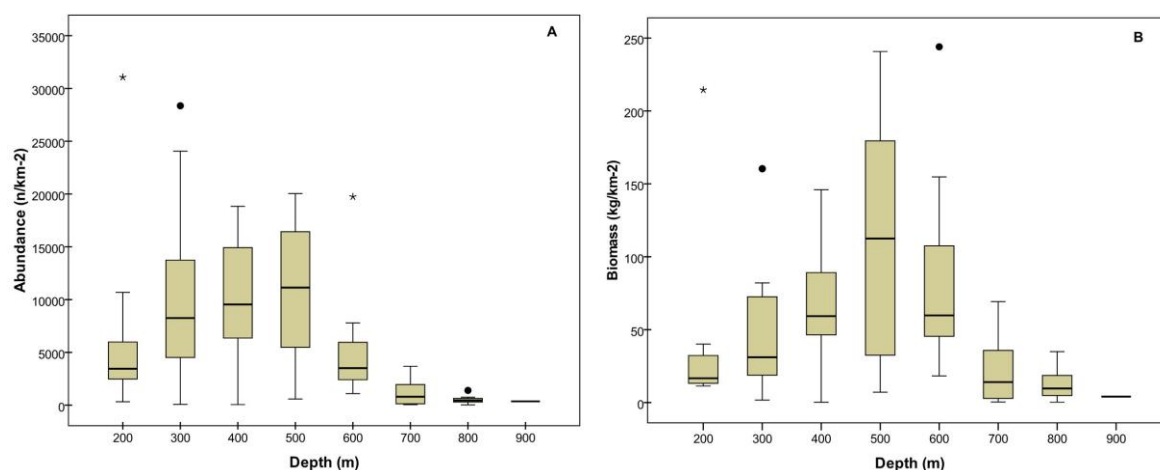
Source	d.f	S	d	J'	H'	D	BI	Post-hoc test (Tamhane's T2)
Stratum	67	0.001**	0.013*	0.000**	0.013*	0.000**	0.000**	D 700 and 800 vs 200, 300,400,500 and 600
Season	3	0.002**	0.000**	0.226	0.017*	0.448	0.086	
Strat.xSeason	17	0.785	0.830	0.057	0.223	0.507	0.273	BI 600 vs 800

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			

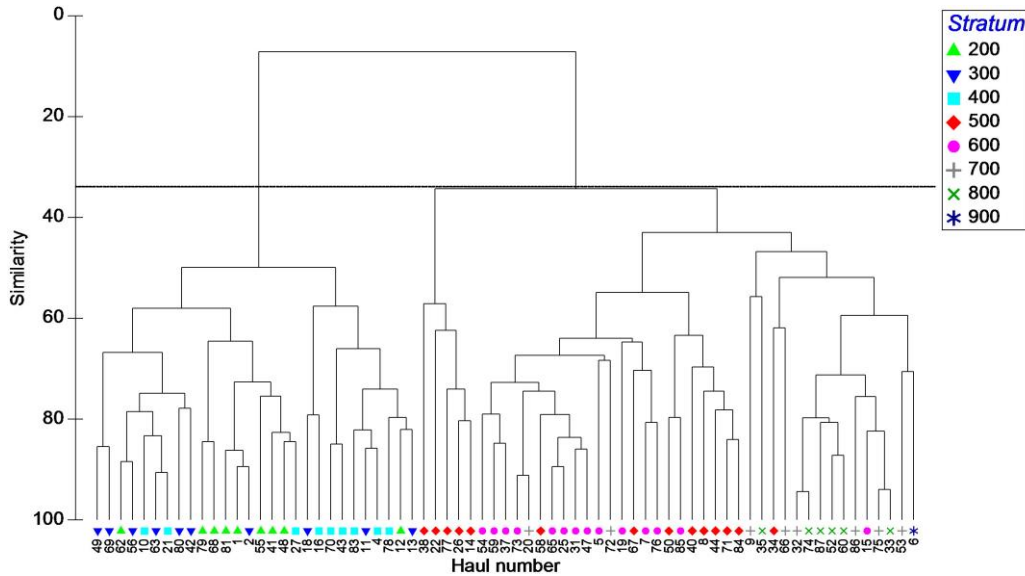


Figure 3. Cluster results of experimental hauls at eight depth strata in bathyal ground in Antalya Bay, eastern Mediterranean, obtained with group average clustering method and percent similarity resemblance measure on abundance of decapod crustaceans obtained. The upper line indicates groups at the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

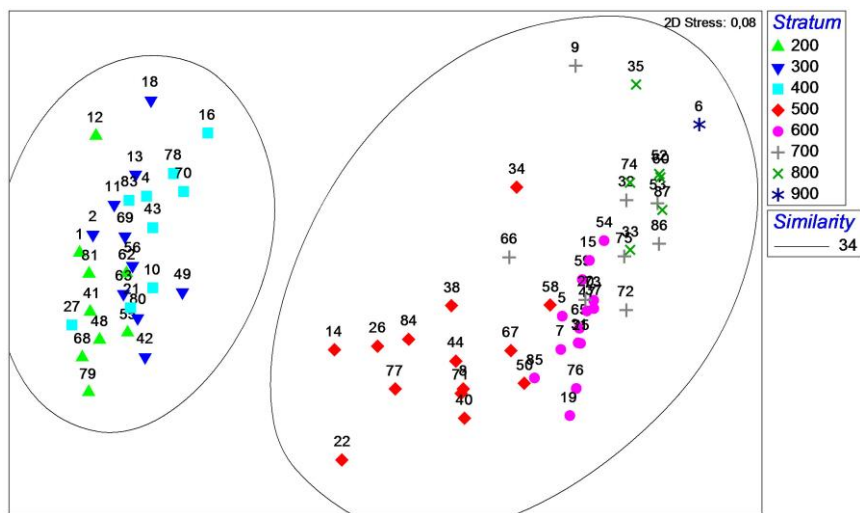


Figure 4. MDS ordination plot of abundance data of decapods crustaceans obtained by each haul during the survey.

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.heterocarpus* 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/km², with maximum of 30 830 n/km² 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/km²,

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

with maximum of 11 588 n/km² in the 600 meters stratum.

Bio-Ecological 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 macroplankton 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 macroplankton feeders, migrator

macroplankton 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

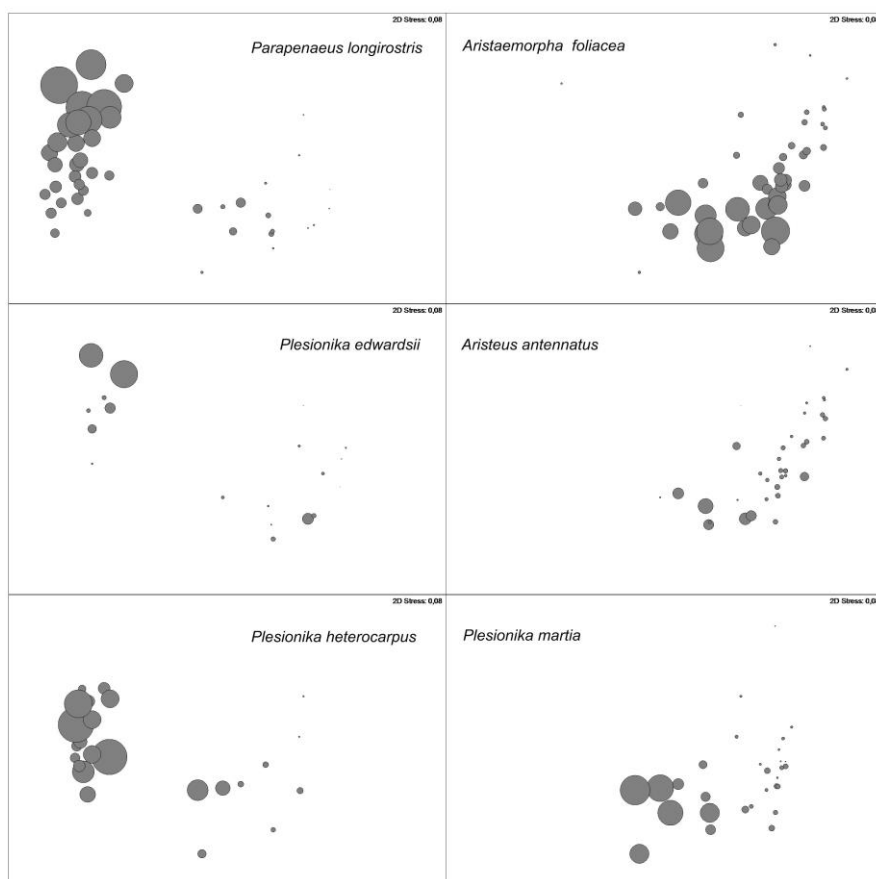


Figure 5. The bubble plots of nMDS ordination derived from the abundance data of the most typified six species between stratum in upper and middle slopes. Circle diameter is proportional to the abundance. The largest circle corresponds to the maximum abundance (31 000 n/km²) of each species.

Table 9. Distribution of decapod crustaceans collected in the bathyal ground off Antalya Bay according the Bio-ecological categories (M:mesopelagic, N:nekto-benthic, B:benthic) and feeding guilds (mM: migrator macroplankton feeder; nmM:non-migrator macroplankton 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
Feeding 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 decapod new or rare species have been recorded (Deval & Frogli, 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 & Frogli, 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 & Kaporis, 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 (Kaporis, Thessalou-Legaki, and Moraitou-Apostolopoulou, 2000; Papakonstantinou & Kaporis, 2001; 2003; Politou et al., 2005). Kaporis, Dogrammatzi, Christidis, Maina, & Kladoudatos (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 (Kaporis 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 & Gjikhuri, 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 macroplankton 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 Mediterranean (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.

Acknowledgements

The authors deeply thank the captain and the crew of the R/V “Akdeniz Su”, and the Ph.D. students, Olgaç Güven, Turhan Kebapçioğlu, Yasemin Kaya, and MSc students İsmet Saygu and Gökçe Özgen for their help during the work at sea. This study was financed partially by the Akdeniz University Research Fund, Projects No: 2010.01.0111.001 and 2011.02.0121.022.

References

- Abelló, P., Valladares, F.J., & Castellón, P. (1988). Analysis of the structure of decapod crustacean assemblages off the Catalan coast (North-West Mediterranean). *Marine Biology*, 98, 39-49. <http://dx.doi.org/10.1007/BF00392657>.
- Abelló, P., Carbonell, A., & Torres, P. (2002). Biogeography of epibenthic crustaceans on the shelf and upper slope off the Iberian Peninsula Mediterranean coasts: implications for the establishment of natural management areas. *Scientia Marina*, 66 (Suppl. 2), 183-198. <http://dx.doi.org/10.3989/scimar.2002.66s2183>
- Ateş, A., Katağan, T., & Kocataş, A. (2006). Bathymetric distribution of decapod crustaceans on the continental shelf along the Aegean coasts of Turkey. *Crustaceana*, 79(2), 129-141. <http://dx.doi.org/10.1163/156854006776952928>
- Bertrand, J.A., Gil De Sola, L., Papaconstantinou, C., Relini, G., & Souplet, A. (2002). The general specifications of the MEDITS surveys. *Scientia Marina*, 66(Suppl.2), 9-17. <http://dx.doi.org/10.3989/scimar.2002.66S29>.
- Bray, J.R., & Curtis, J.T. (1957). An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs*, 27(4), 325-349. <http://dx.doi.org/10.2307/1942268>.
- Brian, A. (1931). La biologia del fondo a “Scampi” nel Mar Ligure. *Aristaeomorpha, Aristeus* ed altri macruri natanti. *Bollettino dei Musei di Zoologia ed Anatomia comparata della R. Università di Genova*, 11, 1-6.
- Cartes, J.E. (1993). Deep-sea decapods fauna of the western Mediterranean: Bathymetric distribution and biogeographic aspects. *Crustaceana*, 65(1), 29-40. <http://dx.doi.org/10.1163/156854093x00342>.
- Cartes, J.E. (1998). Feeding strategies and partition of food resources in deep-water decapod crustaceans (400–2300 m). *Journal of the Marine Biological Association of the United Kingdom*, 78(02), 509-524. <http://dx.doi.org/10.1017/s002531540004159x>.
- Cartes, J.E., & Sardà, F. (1992). Abundance and diversity of decapod crustaceans in the deep-Catalan Sea (Western Mediterranean). *Journal of Natural History*, 26, 1305–1353. <http://dx.doi.org/10.1080/00222939200770741>.
- Cartes, J.E., Sorbe, J.C., & Sardà, F. (1994). Spatial distribution of deep-sea decapods and euphausiids near the bottom in the northwestern Mediterranean. *Journal of Experimental Marine Biology and Ecology*, 179, 131-144. [http://dx.doi.org/10.1016/0022-0981\(94\)90021-3](http://dx.doi.org/10.1016/0022-0981(94)90021-3).
- Cartes, J.E., Abelló, P., Lloris, D., Carbonell, A., Torres, P., Maynou, F., & Gil de Sola, L. (2002). Feeding guilds of western Mediterranean demersal fish and crustaceans: an analysis based in a spring survey. *Scientia Marina*, 66 (Suppl.2), 209-220. <http://dx.doi.org/10.3989/scimar.2002.66s2209>.
- Cartes, J.E., Maynou, F., Sardà, F., Company, J.B., Lloris, D., & Tudela, S. (2004). The Mediterranean deep-sea ecosystems: an overview of their diversity, structure, functioning and anthropogenic impacts. In: *The Mediterranean deep-sea ecosystems: an overview of their diversity, structure, functioning and anthropogenic impacts, with a proposal for conservation*. (pp. 9-38), IUCN, Málaga and WWF, Rome, 66 pp.
- Cartes, J.E., Huguet, C., Parra, S., & Sanchez, F. (2007). Trophic relationships in deep-water decapods of Le Danois bank (Cantabrian Sea, NE Atlantic): Trends related with depth and seasonal changes in food quality and availability. *Deep Sea Research Part I: Oceanographic Research Papers*, 54(7), 1091-1110. <http://dx.doi.org/10.1016/j.dsr.2007.04.012>.
- Cartes, J.E., Maynou, F., Fanelli, E., Papiol, V., & Lloris, D. (2009). Long-term changes in the composition and diversity of deep-slope megabenthos and trophic webs off Catalonia (western Mediterranean): Are trends related to climatic oscillations? *Progress in Oceanography*, 82(1), 32-46. <http://dx.doi.org/10.1016/j.pocean.2009.03.003>.
- Çınar, M.E., Katağan, T., Öztürk, B., Dağlı, E., Açıık, S., Bitlis, B., Bakır, K., & Doğan, A. (2012). Spatio-temporal distributions of zoobenthos in Mersin Bay (Levantine Sea, eastern Mediterranean) and the importance of alien species in benthic communities. *Marine Biology Research*, 8(10), 954-968. <http://dx.doi.org/10.1080/17451000.2012.706305>.
- Clarke, K.R., & Gorley, R.N. (2006). *PRIMER version 6: user manual/tutorial*. PRIMER-E, Plymouth, UK, 192 pp.
- Colloca, F., Cardinale, M., Belluscio, A., & Ardizzone, G. (2003). Pattern of distribution and diversity of demersal assemblages in the central Mediterranean sea. *Estuarine, Coastal and Shelf Science*, 56, 469–480. [http://dx.doi.org/10.1016/s0272-7714\(02\)00196-8](http://dx.doi.org/10.1016/s0272-7714(02)00196-8).
- Company, J.B., Maiorano, P., Tselepides, A., Politou, C.-Y., Plaity, W., Rotllant, G., & Sardà, F. (2004). Deep-sea decapod crustaceans in the western and central Mediterranean Sea: preliminary aspects of species distribution, biomass and population structure. *Scientia Marina*, 68 (Suppl. 3), 73–86. <http://dx.doi.org/10.3989/scimar.2004.68s373>.
- Danovaro, R., Dinet, A., Duineveld, G., & Tselepides, A.

- (1999). Benthic response to particulate fluxes in different trophic environments: a comparison between the Gulf of Lions Catalan Sea (western Mediterranean) and the Cretan Sea (eastern Mediterranean). *Progress in Oceanography*, 44, 287–312. [http://dx.doi.org/10.1016/S0079-6611\(99\)00030-0](http://dx.doi.org/10.1016/S0079-6611(99)00030-0).
- Deval M.C., Bök, T., Ateş, C., Ulutürk, T., & Tosunoğlu, Z. (2009). Comparison of the size selectivity of diamond (PA) and square (PE) mesh codends for deepwater crustacean species in the Antalya Bay, eastern Mediterranean. *Journal of Applied Ichthyology*, 25, 372-380. <http://dx.doi.org/10.1111/j.1439-0426.2009.01239.x>.
- Deval M.C., & Kapiris, K. (2016). A review of biological patterns of the blue-red-shrimp *Aristeus antennatus* (Risso, 1816) along the Mediterranean Sea: a case study of the Antalya's Bay population, eastern Mediterranean Sea. *Scientia Marina*, 80(3), 339-348. <http://dx.doi.org/10.3989/scimar.04411.22A>.
- Deval M.C., & Froglija, C. (2016). New and rare records of deep-sea decapod crustaceans in the Turkish Mediterranean Sea (north Levant Sea). *Zoology in the Middle East*, 62(4), 323-330. <http://dx.doi.org/10.1080/09397140.2016.1250709>.
- Fanelli, E., Papiol, V., Cartes, J.E., Rumolo, P., & López-Pérez, C. (2013). Trophic webs of deep-sea megafauna on mainland and insular slopes of the NW Mediterranean: a comparison by stable isotope analysis. *Marine Ecology Progress Series*, 490, 199-221. <http://dx.doi.org/10.3354/meps10430>.
- Follesa, M.C., Porcu, C., Gastoni, A., Mulas, A., Sabatini, A., & Cau, A. (2009). Community structure of bathyal decapod crustaceans off South-Eastern Sardinian deep-waters (Central-Western Mediterranean). *Marine Ecology*, 30(Suppl.1), 188-199. <http://dx.doi.org/10.1111/j.1439-0485.2009.00323.x>.
- Gramolini, R., Mannini, P., Milone, N., & Zeuli, V. (2005). *AdriaMed Trawl Survey Information System (ATrIS): User Manual*. GCP/RER/010/ITA/TD17. *AdriaMed Technical Documents*, 17, 141 pp.
- Hopkins, T.L., Flock, M.E., Gartner, J.V., & Torres, J.J. (1994). Structure and trophic ecology of a low latitude midwater decapod and mysid assemblage. *Marine Ecology Progress Series*, 109, 143-156. <http://dx.doi.org/10.3354/meps109143>.
- Kapiris, K., Thessalou-Legaki, M., & Moraitou-Apostolopoulou, M. (2000). Population characteristics and feeding parameters of *Aristaeomorpha foliacea* and *Aristeus antennatus*. In: J.C. Von Voupel Klein & F.R. Shram (Eds.), *The Biodiversity Crisis and Crustacea* (pp. 177-191). Rotterdam, Netherlands, A.A. Publishers, 853 pp.
- Kapiris K., Thessalou-Legaki, M., Petrakis, G., & Conides, A. (2010). Ontogenetic shifts and temporal changes the trophic patterns of deep-sea red shrimp *Aristaeomorpha foliacea* (Decapods, Aristeidae) in the E. Ionian Sea (E. Mediterranean). *Marine Ecology*, 31(2), 341-354. <http://dx.doi.org/10.1111/j.1439-0485.2009.00344.x>.
- Kapiris, Dogrammatzi, K., Christidis, G., Maina, I., & Klaoudatos, D. (2014). Decapod crustacean fauna of the Argolikos Gulf (Eastern Mediterranean, Central Aegean Sea). *Acta Adriatica*, 55 (2), 219-228.
- Katağan, T., Kocataş, A., & Benli, H.A. (1988). Note Préliminaire Sur Les Décapodes Bathyaux De La Cote Turque De La Mer Egée. *Rapp. Comm. Int. Mer. Médit.*, 31(2), 1-23.
- Koçak, C., Kırkım, F., & Katağan, T. (2010). Anomuran (Crustacea, Decapoda) fauna of Fethiye Bay (Turkey, eastern Mediterranean). *Turkish Journal of Zoology*, 34: 333-342. <http://dx.doi.org/10.3906/zoo-0902-2>.
- Madurell, T., Cartes, J.E., & Labropoulou, M. (2004). Changes in the structure of fish assemblages in a bathyal site of the Ionian Sea (eastern Mediterranean). *Fisheries Research*, 66, 245-260. [http://dx.doi.org/10.1016/S0165-7836\(03\)00205-4](http://dx.doi.org/10.1016/S0165-7836(03)00205-4).
- Matarrese, A., D'Onghia, G., Tursi, A., & Maiorano, P. (1997). Vulnerabilità e Resilienza in *Aristaeomorpha foliacea* (Risso, 1827) E *Aristeus antennatus* (Risso, 1816) (Crustacei, Decapodi) Nel Mar Ionio. *S.It.E. Atti*, 18, 535-538.
- Maynou, F., & Cartes, J.E. (2000). Community structure of bathyal decapod crustaceans off south-west Balearic Islands (western Mediterranean): seasonality and regional patterns in zonation. *Journal of the Marine Biological Association of the United Kingdom*, 80(5), 789-798. <http://dx.doi.org/10.1017/S0025315400002769>
- Moranta J., Quetglas, A., Massutí, E., Guijarro, B., Hidalgo, M., & Diaz, P. (2008). Spatio-temporal variations in deep-sea demersal communities off the Balearic Islands (western Mediterranean). *Journal of Marine Systems*, 71, 346–366. <http://dx.doi.org/10.1016/j.jmarsys.2007.02.029>
- Murenu, M., Cuccu, D., Follesa, C., Sabatini, A., & Cau, A. (1994). The occurrence of *Aristaeomorpha foliacea* in Sardinian waters. In: *Life Cycles and Fisheries of the Deep-water Red Shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus**. Proc. of the International workshop held in the Istituto di Tecnologia della Pesca e del Pescato. Bianchini M.L. and S. Ragonese (editors), N.T.R. - I.T.P.P.: 49-50
- Orsi Relini, L., & Relini, G. (1985). The red shrimps fishery in the Ligurian Sea: Mismanagement or not? *FAO Fish. Rep.*, 336, 99-106
- Palmas, F., Addis, P., Cabiddu, S., Cuccu, D., Follesa, M.C., Mura, M., Olita, A., Pesci, P., & Sabatini, A. (2015). Distribution of spawning and nursery grounds for deep-water red shrimps in the central western Mediterranean Sea. *Mediterranean Marine Science*, 16(1), 117-127. <http://dx.doi.org/http://dx.doi.org/10.12681/mms.859>
- Papaconstantinou, C., & Kapiris, K. (2001). Distribution and population structure of the red shrimp (*Aristeus antennatus*) on an unexploited fishing ground in the Greek Ionian Sea. *Aquatic Living Resources*, 14(05), 303-312. [http://dx.doi.org/10.1016/S0990-7440\(01\)01128-7](http://dx.doi.org/10.1016/S0990-7440(01)01128-7)
- Papaconstantinou, C., & Kapiris, K. (2003). The biology of the giant red shrimp (*Aristaeomorpha foliacea*) at an unexploited fishing ground in the Greek Ionian Sea. *Fisheries Research*, 62(1), 37-51. [http://dx.doi.org/10.1016/S0165-7836\(02\)00254-0](http://dx.doi.org/10.1016/S0165-7836(02)00254-0)
- Papiol, V., Cartes, J.E., Fanelli, E., & Rumolo, P. (2013). Food web structure and seasonality of slope megafauna in the NW Mediterranean elucidated by stable isotopes: relationship with available food sources. *Journal of Sea Research*, 77, 53-69. <http://dx.doi.org/10.1016/j.seares.2012.10.002>
- Patania A., & Mutlu, E. (2015). The occurrence of the non-native species *Sicyonia lancifer* (Olivier, 1811) belonging to Sicyoniidae family is reported for the

- first time in the Mediterranean Sea. In the following paper the distinguishing features of the species are provided. *Mediterranean Marine Science*, 1(5), 1-4. <http://dx.doi.org/10.12681/mms.1457>
- Politou, C.Y., Maiorano, P., D'Onghia, G., & Mytilineou, Ch. (2005). Deep-water decapod crustacean fauna of the Eastern Ionian Sea. *Belgian Journal of Zoology*, 135(2), 235-241. <http://dx.doi.org/10.11.1.375.9531>
- Relini G., & Orsi Relini, L. (1987). The decline of red shrimp stocks in the gulf of Genoa. *Investigacion Pesquera*, 51(Suppl. 1), 245-260. <http://dx.doi.org/10.11.1.529.8304>
- Sardà, F., Cartes, J.E., & Company, J.B. (1994). Spatio-temporal variations in megabenthos abundance in three different habitats of the Catalan deep-sea (Western Mediterranean). *Marine Biology*, 120, 211-219. <http://dx.doi.org/10.1007/bf00349681>
- Sardà, F., Calafat, A., Mar Flexas, M., Tselepides, A., Canals, M., Espino, M., & Tursi, A. (2004). An introduction to Mediterranean deep-sea biology. *Scientia Marina*, 68, 7-38. <http://dx.doi.org/10.3989/scimar.2004.68s37>
- Soto, L.A. (1985). Distributional patterns of deep-water brachyuran crabs in the Straits of Florida. *Journal of Crustacean Biology*, 5(3), 480-499. <http://dx.doi.org/10.2307/1547920>
- Stergiou K.I., Christou E.D., Georgopoulos, D., Zenetos, A., & Souvermezoglou, C. (1997). The Hellenic seas: physics, chemistry, biology and fisheries. *Oceanography and Marine Biology*, 35, 415-538
- SPSS, 2008. *Statistics for Windows, Version 17.0*. Chicago: SPSS Inc.
- Ungaro, N., Marano, C.A., Marsan, R., Martino, M., Marzano, M.C., Strippoli, G., & Viora, A. (1999). Analysis of demersal species assemblages from trawl surveys in the South Adriatic Sea. *Aquatic Living Resources*, 12(3), 177-185. [http://dx.doi.org/10.1016/S0990-7440\(00\)88469-7](http://dx.doi.org/10.1016/S0990-7440(00)88469-7)
- Vaso, A., & Gjiknuri, L. (1993). Decapod crustaceans of the Albanian coast. *Crustaceana* 65(3), 390-407. <http://dx.doi.org/10.1163/156854093x00810>
- Wenner, E.L., & Boesch, D.F. (1979). Distribution patterns of epibenthic decapods Crustacea along the shelf-slope coenocline, Middle Atlantic Bight, USA. *Bulletin of the Biological Society of Washington*, 3, 106-133