Turkish Journal of Zoology
http://journals.tubitak.gov.tr/zoology/
Research Article

Turk J Zool
(2013) 37: 262-276

doi:10.3906/zoo-1204-33

Depth-related gradient of soft-bottom crustacean distribution along the Cilician shelf*

Erhan MUTLU[1,], Mehmet Betil ERGEV[2]**
[1]Fisheries Faculty, Akdeniz University, 07050 Antalya, Turkey
[2]Derinsu Underwater Engineering and Consulting Company, Kavaklıdere, 06680 Ankara, Turkey

Received: 26.04.2012 • **Accepted:** 20.10.2012 • **Published Online:** 29.04.2013 • **Printed:** 29.05.2013

Abstract: Distribution of crustaceans in 3 transects (including depths of 10, 25, 50, 75, 100, and 200 m) of oligotrophic soft bottoms of the Levantine Sea shelf located near Kumkuyu, Limonlu, and Erdemli was studied in 2000 to show its association with depth-dependent environmental parameters in representative months of each season (winter, spring, summer, and autumn). A total of 90 crustacean species was found; species richness was highest in winter and autumn and between 50 and 100 m in depth. There was a peak value in abundances in the warm season and at a depth interval of 10 to 50 m, whereas highest values of biomass were recorded in May and August and at a depth of 25 m. A seasonal variation at depths shallower than 75 m was observed for evenness values, which were more stable in deeper waters in all seasons. Two main crustacean assemblages were determined, the first corresponding to shallow bottoms (10, 25–100 m) and the other to deeper bottoms (150–200 m). Besides the grain size and total organic carbon content of the sediment, depth is the most important factor in determining the crustacean assemblage. Hydrographic characteristics of the water column made up 2 seasonal crustacean assemblages: the first in February and May, and the other in August and November. Therefore, all factors governing the crustacean distribution were found to be related to the bottom depth.

Key words: Zoobenthos, crustaceans, distribution, eastern Mediterranean shelf

1. Introduction

Overall, distribution of marine benthic communities is affected on a spatial scale by bottom depth, latitude, and longitude (Nybakken, 1982; Coleman et al., 2007) and temporally by the great environmental variability in littoral ecosystems (Rhoads and Young, 1970). Therefore, such combination of the factors governing benthic community distribution could result from variation of depth-related sedimentary, hydrographical, and biological characteristics (Gray, 1981; Karakassis and Eleftheriou, 1997). In order to determine the state of the benthic ecosystem (Ghertsos et al., 2000), the spatial and temporal distribution of marine soft-bottom species is important in understanding the interactions of organisms with each other and with the environment (Dauvin et al., 2004).

Benthic crustaceans have significant importance in nutrition for demersal fish in different habitats, and they are food sources for humans. They are also reasonable biological indicators for water quality and can be used as material for bioassay experiments. In oligotrophic areas such as the Cilician Basin in the Levant Sea (Yılmaz and Tuğrul, 1998), high prevailing temperatures (13 to 14 °C; Özsoy et al., 1993) and scarcity of food supply (Labropoulou and Kostikas, 1999) could be considered to be factors controlling community structure. Therefore, summer dormancy of Mediterranean benthic taxa is due to energetic constraints as a consequence of seasonal temperature and food availability (Coma et al., 2000).

In the eastern Mediterranean Sea, previous benthic studies were almost exclusively limited to Greek and Israeli waters (Galil and Lewinsohn, 1981; Karakassis and Eleftheriou, 1997; Tom and Galil, 1991; Papazacharias et al., 1998; Conides et al., 1999; Tselepides et al., 2000). Many of the later Turkish studies focused on the native and nonnative species diversity of the crustaceans in the Levantine Sea (Özcan et al., 2006; Bakir et al., 2007; Yokes et al., 2007; Çinar et al., 2006, 2008, 2011; Ateş et al., 2007; Doğan et al., 2008). Nevertheless, some studies were concerned with the spatiotemporal distribution of the macrozoobenthos and its relationship with abiotic parameters, of which the bottom depth was found to be a significant explanatory variable for the benthic assemblages (Mutlu and Ergev, 2008; Mutlu et al., 2010; Mutlu and Ergev, 2012). In Turkish waters of the Levantine Sea, there have been no significant studies to date on the benthic crustaceans that related their distribution to depth-related ecological factors.

* This study was carried out at the Institute of Marine Sciences, Middle East Technical University, Erdemli, Mersin, Turkey, where the authors then worked.
** Correspondence: emutlu@akdeniz.edu.tr

Therefore, the objective of this study was to investigate depth-related ecological factors governing the temporal and spatial distribution of crustaceans in the area and to present a preliminary database of the macrofaunal crustacean diversity in 2000.

2. Materials and methods

This study was carried out on a polygon of the Levantine shelf (Erdemli, Mersin Bay, Turkey) (Figure 1). The study area is fed by the Lamas River and a few streams, which are the major sources of freshwater for the nutrient inputs. Depth contours gradually run with increased depth seaward.

In 2000, the temperature (16 to 30 °C) was homogeneous throughout the column of the shallow site (bottom depth of <25 m). The sea surface temperature was lower (<20 °C) in November to May than in August 2000 (approximately 30 °C). Sea surface salinity increased from the shallow site to deeper waters (38.74 to 39.06 PSU). In the deeper waters (>25 to 200 m deep) of the study area, near-bottom temperature ranged between 15.5 °C (February) and 29.3 °C (August) and near-bottom salinity ranged between 38.08 PSU (May) and 39.95 PSU (August) (Mutlu et al., 2010).

Data of grain sizes, $CaCO_3$ content, and the total organic carbon (TOC) of sediments were used for the present work from a previously published paper (Mutlu et al., 2010). Surface sediments composition did not show a significant variation among the seasons. The bottom of the infralittoral zone was characterized by a low percentage of gravel in the inner shelf. The carbonate zone corresponded to depths of 75–100 m and was composed of an aggregation (12%–20%) of the fraction gravel. The sand content decreased from 100% (inner shelf) to 30% (outer shelf) in contrast to the mud distribution. The silt fraction content varied between 0% and 75% from the coast to offshore. A high percentage of silt (>45%) started to be observed after 120–140 m seaward. Concentration of clay in the sediment was found to be low in May and August, while it was higher in February and November. Clay dominated the bottoms deeper than 100 m. The total carbonate percentages of the bottom sediment ranged from 16% to 55%, and high accumulations were developed in the form of bands over stratification between 80 and 100 m. Overall, the TOC was very low (0.1%–0.40%). All of the above environmental variables and measurements, which were published in a study by Mutlu et al. (2010), were also used for the present study, since both studies were simultaneously conducted during the same sampling. According to Ediger et al. (1997), the gravel percentage of the sediment in Mersin Bay was generally less than 1.5% and the coarse fractions (gravel) occurred in high amounts on the inner shelf (<50 m). Sand and finer grains were regularly variable in depth, whereas carbon contents and gravel contents were locally variable due to the occurrence of a carbonate zone composed of shell fragments between depths of 50 and 100 m in the study area (Ergin, 1996; Ediger et al., 1997).

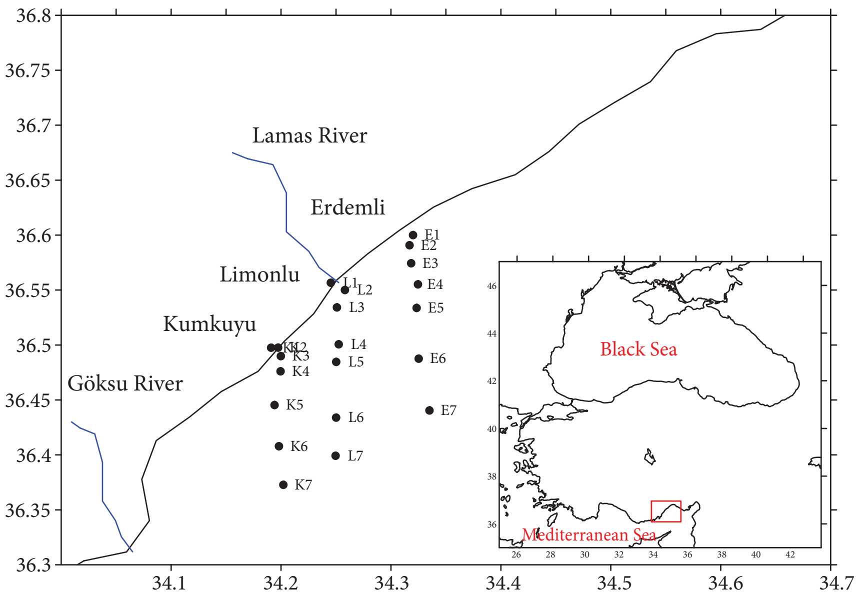


Figure 1. Study area (framed in rectangle) and sampling stations located on soft bottoms (1: 10 m, 2: 25 m, 3: 50 m, 4: 75 m, 5: 100 m, 6: 150 m, and 7: 200 m) across 3 transects, Erdemli (E), Limonlu (L), and Kumkuyu (K), in the Cilician shelf in 2000.

Benthic samples were collected in certain months (February, May, August, and November 2000) representing the seasons of the year (Figure 1) onboard the R/V *Erdemli* (Institute of Marine Sciences, Middle East Technical University [IMS-METU]) at 3 transects in Mersin Bay, i.e. Kumkuyu, Limonlu, and Erdemli. There were 7 different depths at each transect (10, 25, 50, 75, 100, 150, and 200 m). Three replicates were taken with a Van Veen grab (0.10 m^2 sampling surface area) at each depth of each transect at each season. Approximately 0.25 L of sediment was taken from 1 of the replicates and then kept in a freezer for geochemical–physical analysis. Basic physical parameters such as temperature, salinity, and density were measured throughout the water column by using a SeaBird CTD probe. Materials taken for the benthic study were sieved through a set of sieves of decreasing mesh size of 2, 1, and 0.5 mm. The residues retained on each sieve were treated with 5% $MgCl_2$ solutions to loosen the fauna, and then specimens were fixed with 10% formalin–seawater solution buffered with borax.

Benthic crustaceans were sorted out from the residues in the laboratory and then were preserved in 70% alcohol. Crustacean specimens were identified and recognized to the lowest possible taxonomic level, and then the total number of specimens for each species was recorded and weighed by a digital scale to the nearest precision of 0.0001 g.

A set of community parameters, i.e. Shannon–Wiener diversity (H', $\log_2$base), Margalef's species richness (d), and Pielou's evenness (J') indexes, were calculated to compare their variation among sampling sites. In order to determine which ecological parameters were more relevant in governing crustacean distribution, Spearman rank correlations were done among the faunistic and environmental parameters. The Soyer index was used to determine percent dominance (D%). There were no significant differences in crustacean community composition among transects considering the abundance data of taxa in each replicate sample (3-way PERMANOVA, F = 1.04, P = 0.3342, df = 2); therefore, average data were pooled for the transect factor for statistical analysis. Accordingly, all Van Veen replicates from any given depth from the 3 transects were considered together for the analysis. Therefore, sample size (n) for any given sampling depth was 9 for each season. Two-way ANOVA was tested for differences in values of the community parameters among seasons and depths ($P < 0.05$).

The Bray–Curtis dissimilarity matrix calculated from the crustacean abundance data transformed by $\mathrm{Log}_{10} \times (N + 1)$ was tested by 2-way orthogonal nonparametric (permutation-based) MANOVA (PERMANOVA) (Anderson, 2001) to test for differences among sampling sites, with depth as a fixed factor and season as random (Jones, 2002). All statistical analyses were performed with MATLAB (ver.7.0, The MathWorks, Inc.).

To show any depth-related gradient in the crustacean distribution according to environmental variables, a canonical extension of principal component analysis, canonical correlation analysis (CCA) (ter Braak and Smilauer, 2002), was applied to $\mathrm{Log}_{10} \times (N + 1)$ – transformed crustacean abundances (CANOCO 4.5 for Windows). The Monte Carlo test was used for the significance of the ordination axes. A nonparametric multidimensional scaling (nMDS) was applied to similarity measures of the Bray–Curtis index calculated from the transformed abundance data to show the ordination of the crustacean community according to the depth gradient in each season.

3. Results

A total of 90 crustacean species belonging to 9 orders were identified (Figure 2; Appendix). The highest numbers of species corresponded to the orders Decapoda (30 species) and Amphipoda (38 species). The highest dominance index values were found for the amphipod *Ampelisca brevicornis* (Costa, 1853) (80%) and the tanaidacean *Apseudopsis latreillii* (Milne-Edwards, 1828) (60%). Dominance values were less than 50% for 98% of the species. The most abundant species were a tanaidacean species, *A. latreillii* (maximum density of 1177 ind m^{-2} at 50 m in August; Figure 2), and *A. brevicornis* (603 ind m^{-2} at 10 m in May). The number of species was highest in February–November (60 and 53 species, respectively). The numerically dominant species were *A. latreillii*, *A. brevicornis*, and *Harpinia pectinata* Sars, 1891 in February–May; *Upogebia* sp. in August; and *Eriopisa elongata* (Bruzelius, 1859) and *Harpinia antennaria* Meinert, 1890 in November. The number of species (S) was significantly different among depths ($P < 0.05$; Table 1); S ranged from 20 to 47 and peaked at depths of 10 and 75 m. Amphipod (10–150 m depth), decapod (10–100 m), and isopod (50–100 m) species dominated the shelf; the number of species of the taxa decreased thereafter at greater depths (Figure 2). Species diversity was more stable among seasons at the deeper sites (Figure 3). The number of species was positively correlated with temperature of the bottom water and sand content (Spearman rank r = 0.42 for each; n = 43, n = 70, respectively) and negatively correlated with bottom depth (r = –0.44, n = 43, $P < 0.05$), density of bottom water (r = –0.47, n = 43), and silt content (r = –0.37, n = 70, $P < 0.05$).

The highest density was found in August (148 ind m^{-2}), being 3-fold higher than the density in February. However, average abundance showed variations among depths and seasons, and their interaction was significant ($P < 0.05$; Table 1). Crustacean abundances presented a large seasonal fluctuation at sampling sites located between 10 and 50 m when compared to deeper sites (Figure 3).

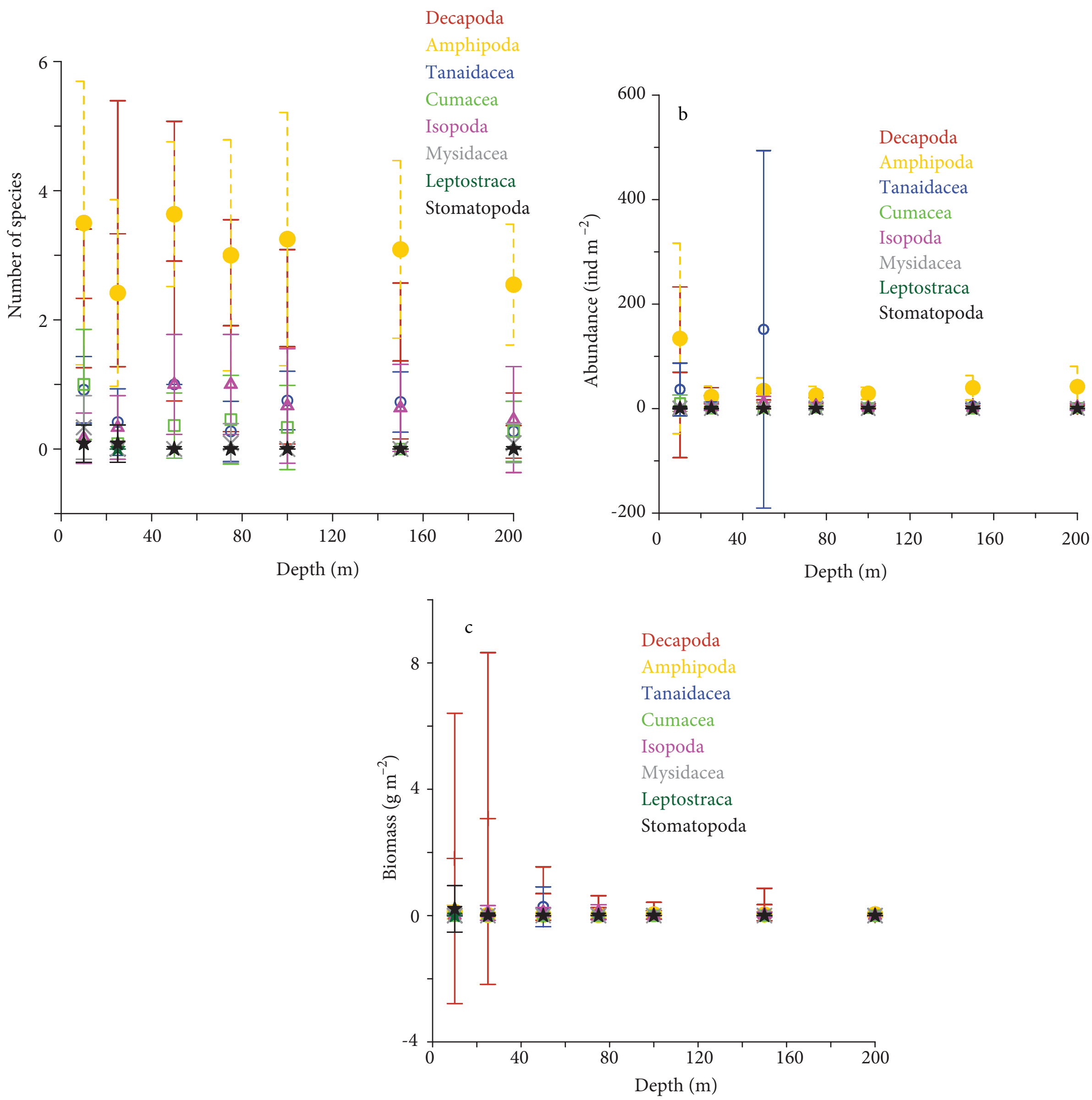


Figure 2. Qualitative and quantitative distribution of crustacean orders at sampled depths. Each point represents the value obtained from averaging values of each parameter across all replicates at each depth (n = 9). Symbols show the averages and vertical bars show ranges of standard deviation (SD). Order Ostracoda is excluded. A) Number of species; B) abundance (ind m^{-2}); C) biomass (g m^{-2}).

Crustacean abundances decreased sharply from 249 ind m^{-2} at 10 m to 59 ind m^{-2} at 25 m, then increased abruptly to 205 ind m^{-2} at 50 m and was about 50 ind m^{-2} at deeper sampling sites (Figure 3). Abundance increased also with increasing sea surface temperature (SST; r = 0.28, n = 56), near-bottom temperature (NBT; r = 0.48, n = 43), and sand content (r = 0.47, n = 70), while it was negatively correlated with bottom depth (r = –0.52, n = 81), near-bottom density (NBD; r = –0.49, n = 43), silt (r = –0.43, n = 81), and clay (r = –0.28, n = 81) content.

A total of 28.76 g biomass and an average biomass value of 0.04 g m^{-2} were measured in the study area. *Goneplax rhomboides* (Linnaeus, 1758) was the dominant species in terms of biomass, comprising 34% of the total biomass. Crustacean biomass values were significantly different among seasons and depths (Table 1; Figure 3). The average biomass value increased from 1.80 g m^{-2} at 10 m to 3.56 g m^{-2} at 25 m, where the annual peak value occurred (Figure 3). The deeper zone had a crustacean biomass of less than 0.6 g m^{-2}. Significant correlations were found between biomass, bottom depth (r = –0.39, n = 81), NBD (r = –0.41, n = 43), and NBT (r = 0.34, n = 43).

Two-way ANOVA showed that there was a significant effect of depth and season on community characteristics;

Table 1. P-values from 2-way analysis of variance for number of species (S), abundance (N), biomass (B), and diversity indexes (species richness, D; evenness, J'; and Shannon–Wiener diversity index, H'). Bold numbers show P < 0.05.

Source	S	N	B	D	J'	H'
Season	0.1157	**0.0003**	**0.0383**	**0.0091**	**0.0012**	**0.0005**
Depth	**0.0000**	**0.0000**	**0.0010**	**0.0002**	**0.0000**	**0.0045**
Season × depth	**0.0036**	**0.0000**	0.2310	0.0919	**0.0002**	**0.0466**

this was also reflected in the diversity, evenness, and species richness index values (P < 0.05; Table 1). The species richness and diversity values had a normal Gaussian distribution across the depth gradient on the shelf. Evenness increased with depth and showed a seasonal fluctuation at depths of between 10 and 50 m (Figure 3). The diversity indexes were significantly higher in February (d = 14.1, J' = 0.76, H' = 3.12) and November (d = 11.4, J' = 0.70, H' = 2.78) than in May and August (d = ~8.0, J' = ~0.60, H' = ~2.10) at P < 0.05. Species richness was highly variable between 75 and 100 m depth (d = 2.11–4.82) (Figure 3). Evenness was significantly lower at 10 m (J' = 0.56) and 50 m (J' = 0.43) than at deeper sites (J' = 0.73–0.82) (Figure 3). The Shannon–Wiener index fluctuated in the deeper zone (50–100 m; Figure 3) among seasons. Overall, biotic parameters were generally correlated with bottom depth (d: r = –0.33, n = 80; J': r = 0.34, n = 79) and NBD (d: r = –0.36, n = 43; J': r = 0.35, n

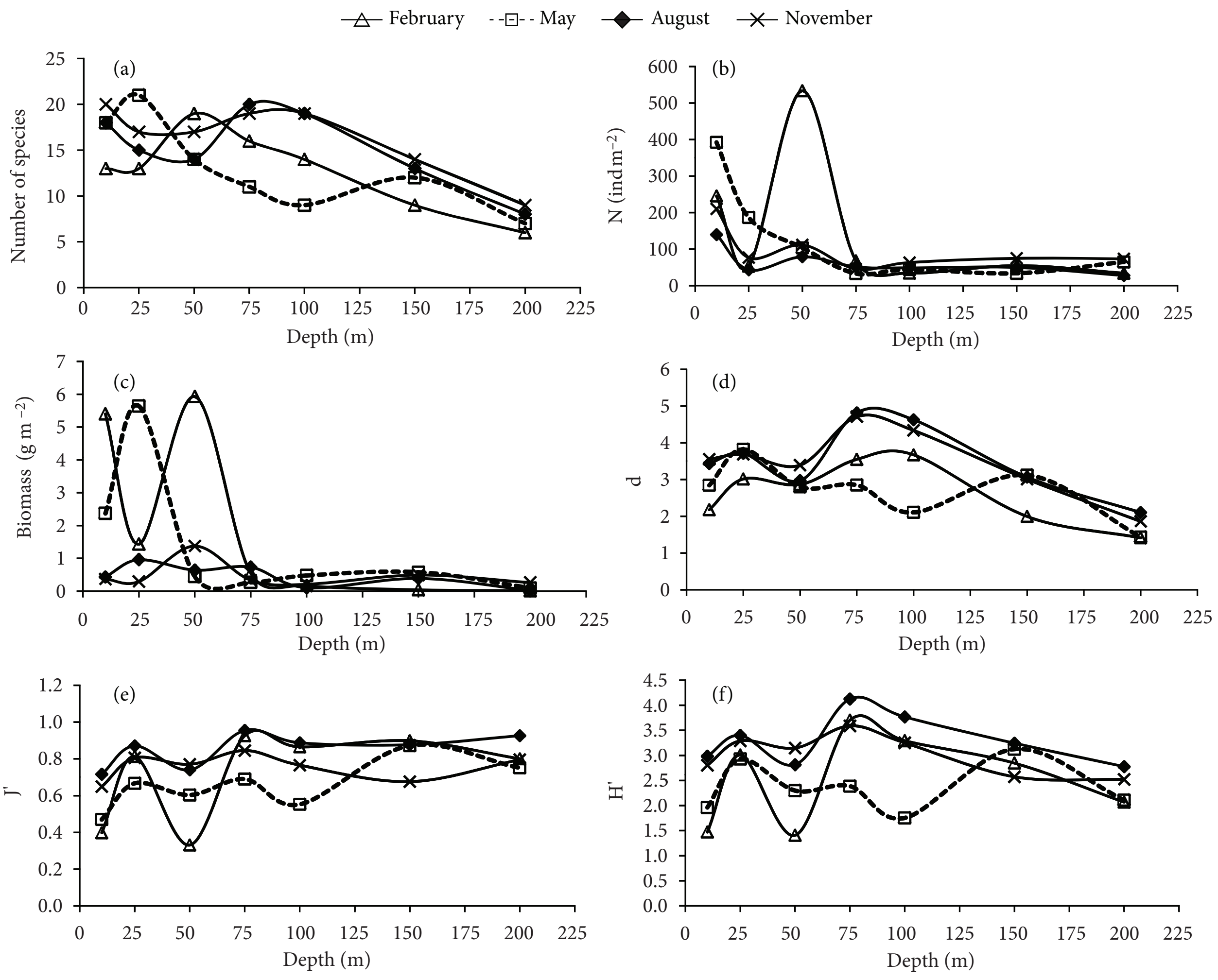


Figure 3. Spatiotemporal (depths and months) and annual (average) changes of crustacean faunistic parameters on the Cilician shelf for number of crustacean species (S), density (N), biomass, species richness (d), evenness (J'), and Shannon–Wiener diversity (H') indexes. Each point represents the value obtained from averaging values of each parameter across all replicates at each depth (n = 9).

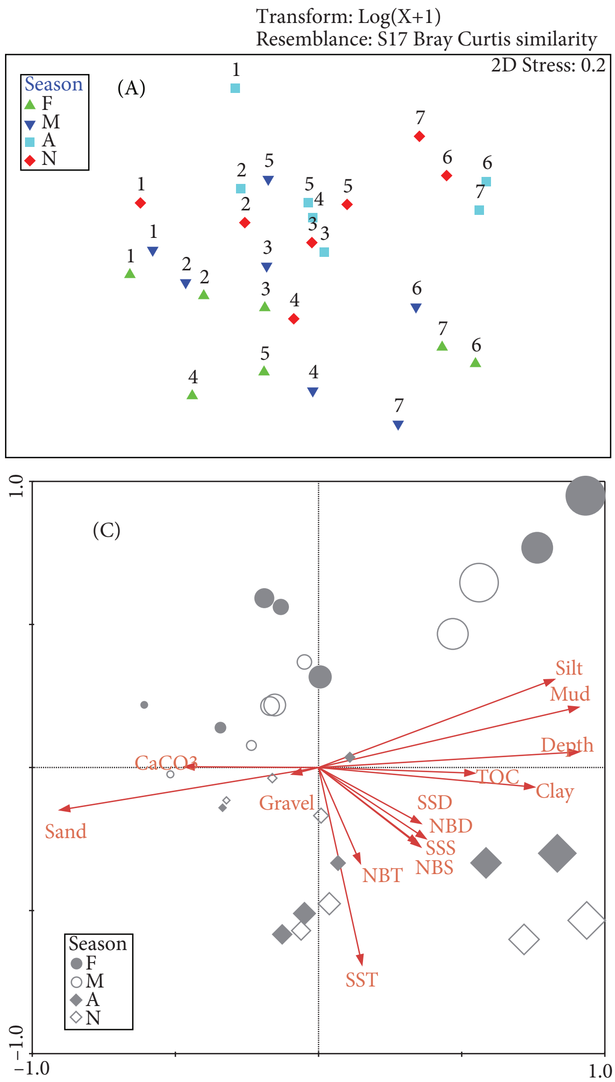
= 43), and subsequently with NBT (J': r = –0.37, n = 43), sand (d: r = 0.36, n = 68; J': r = –0.31, n = 68), and silt (d: r = –0.32, n = 69; J': r = 0.30, n = 68) contents at $P < 0.05$. Two-way PERMANOVA showed that there were significant differences in the crustacean distribution in relation to depth, season, and their interaction ($P < 0.05$; Table 2).

In general, distribution of crustacean assemblages along the shelf was related to bottom depth and depth-related sediment features. Two main groups were detected, which comprised shallow-water (10, 25–100 m) and deep-water (150–200 m) sampling sites (Figure 4). The shallow water had 2 subentities corresponding to 1) very shallow (10 m) and 2) deep shallow (25–100 m) sites. Seasonal

Table 2. Nonparametric (permutation-based) MANOVA. Depth is fixed and season is random. Bold numbers show P < 0.05.

Source	df	SS	MS	F	P
Depth	6	6.8839	1.1473	3.1011	**0.0002**
Season	3	2.7819	0.9273	2.5064	**0.0002**
Depth × season	18	6.6594	0.3700	2.4424	**0.0002**
Residual	55	8.3313	0.1515		
Total	82	24.6566			

No. of iterations = 5000.



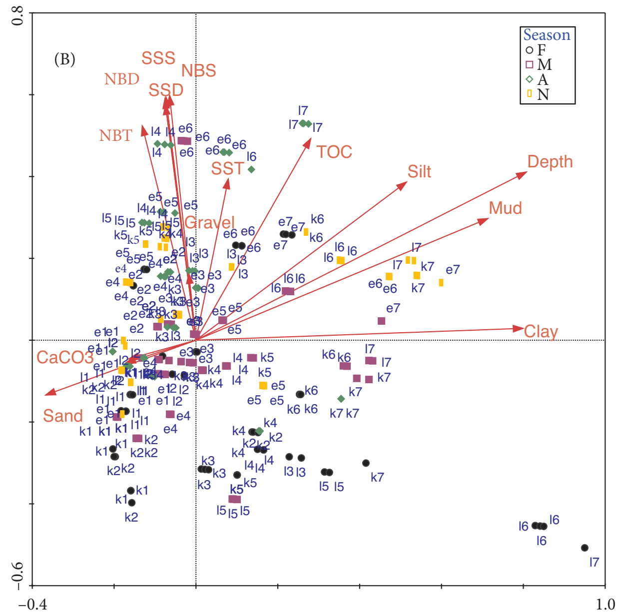


Figure 4. nMDS (A; see Figure 1 for depth code) and biplot of CCA (axes 1–2) performed on log-transformed ($\log_{10} \times [N + 1]$) density values (N) of the crustacean taxa and environmental variables (arrows) at each replicate (B; see Figure 1 for depth and transect codes around the symbols) and at 7 depths of a combination of 3 transects each, including 7 stations (C) in each season. Arrows refer to the direction and relative importance of environmental variables in the ordination. Symbol size is proportional to depth of sampling sites variable, i.e. the largest symbol corresponds to the maximum depth. See Table 3 for the abbreviations of the environmental variables.

Table 3. Summary of statistical measures of the characteristics of crustacean species abundance and environmental variables for CCA (SST: sea surface temperature; NBT: near-bottom temperature in °C; SSS and NBS: shallow-site salinity and near-bottom salinity, respectively; SSD and NBD: water density sigma-theta for shallow sites and near-bottom sites, respectively; grain size in %; $CaCO_3$: total carbonate content in %; TOC: total organic carbon content in % of sediment).

Environmental variables	Species axis 1	Species axis 2
Depth	**0.8873**	0.0521
SST	0.1479	**–0.6591**
NBT	0.1423	–0.3199
SSS	0.3476	–0.2654
NBS	0.3386	–0.2548
SSD	0.3485	–0.1871
NBD	0.3658	–0.238
Gravel	–0.0904	–0.0224
Sand	**–0.8815**	–0.1422
Silt	**0.8030**	0.2947
Clay	**0.7351**	–0.0655
Mud	**0.8858**	0.2018
$CaCO_3$	**–0.4571**	0.0026
TOC	**0.5315**	–0.019
Eigenvalues	0.441	0.371
Species–environment correlations	0.976	0.957
Cumulative percentage variance		
of species data	8.6	15.9
of species–environment relation	15.5	28.5

differences among samples from the same depth were also observed in the CCA and nMDS ordination; this pattern was more pronounced in samples below 50 m (Figure 4). For each depth, samples from February–May and August–November were more similar to others of the same timespan than to those of the other period. Nine of the 14 environmental parameters were explained by the first 2 CCA axes for the benthic community variables, with 28.5% of the total variation (Table 3; Figure 5). The first CCA axis had the strongest correlations with 4 of these environmental parameters, which were associated mostly with depth gradient and fine-grain sedimentary fractions (Table 3; Figure 5). Physical parameters of the water had the highest correlation with the second CCA axis (Table 3). Samples were ordinated according to sand content (shallow-water sites) and muddy fractions (deep-water sites) (Figure 5). TOC had a moderate correlation with the crustacean assemblages (Table 3; Figure 5). Validity of the significance of both the first canonical axis (Table 3; F = 1.325, P = 0.036) and all the axes (F = 1.360, P = 0.002) were proved by the Monte Carlo test.

Abundance of species in assemblages determined according to axis 2 of the CCA is given in Table 4. Seasonal differences in assemblages were more prominent in deeper sampling sites. It is noteworthy to mention that the sedimentary parameters were significantly correlated with the bottom depth and all hydrographical variables (with the exception of NBT at P < 0.05), whereas NBD was not significantly correlated with the depth (Table 5). Depth-related sedimentary and hydrographical variables were most likely to be the controlling factors at a temporal scale of the shallow water communities (Table 5). Six species discriminated the crustacean assemblage structure effectively between February and May (F–M) and August and November (A–N) at 10 m, 2 species at 25–100 m, and 4 species at 150–200 m (Table 4). Two decapods (*Diogenes pugilator* [Roux, 1829] and *Upogebia* sp.), 3 amphipods (*A. brevicornis*, *Medicorophium* sp., and *Ericthonius punctatus*

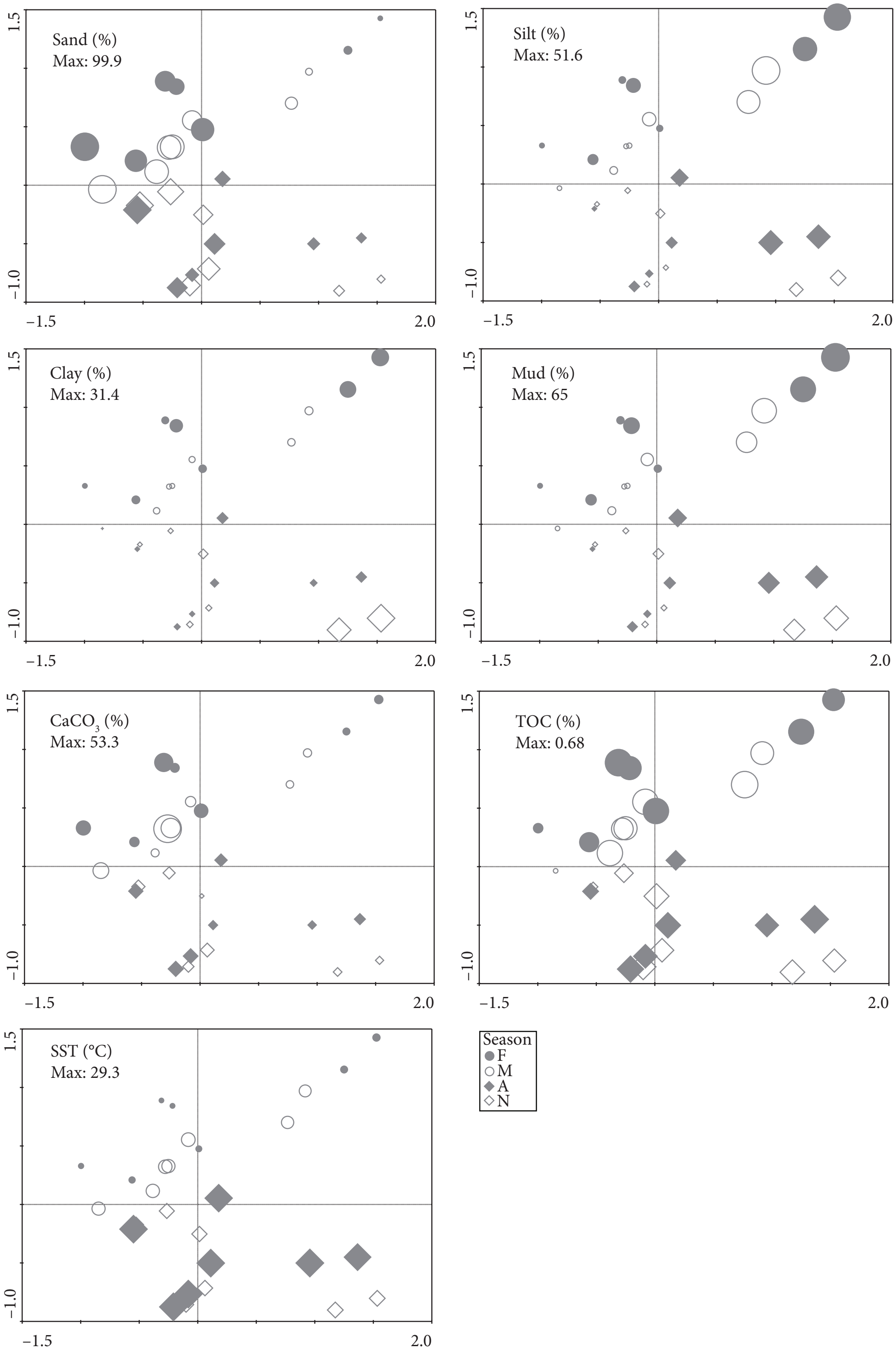


Figure 5. CCA ordination of species (based on abundance data) with superimposed symbols representing bottom depth (see Figure 4), sedimentary parameters, and sea surface temperature of the sampling locations in February (F), May (M), August (A), and November (N). Symbol size is proportional to value of each variable, i.e. the largest symbol corresponds to the maximum value.

Table 4. Average abundances of the crustacean species according to depth and groups of seasons as determined by CCA (February–May: F–M; August–November: A–N). Asterisk(s) indicate(s) abundant species at: *, 10 m; **, 25–100 m; *** 150–200 m.

Seasons	F–M	A–N	F–M	A–N	F–M	A–N
Species/depth (m)	10	10	25–100	25–100	150–200	150–200
**Diogenes pugilator* (Roux, 1829)	16.25	0.56	0.11	0.14	0.00	0.00
**Upogebia* sp.	0.00	92.22	0.63	0.56	0.00	0.36
**Ampelisca brevicornis* (Costa, 1853)	142.50	46.67	12.57	18.21	3.51	5.21
****Cheirocratus sundevalli* (Rathke, 1843)	0.00	0.00	0.00	0.00	7.43	0.00
****Eriopisa elongata* (Bruzelius, 1859)	0.00	0.00	0.14	2.27	3.65	14.50
**Medicorophium* sp.	12.50	0.00	1.61	3.98	0.00	0.00
**Ericthonius punctatus* (Bate, 1857)	15.83	0.00	0.93	0.78	0.00	0.00
****Harpinia antennaria* Meinert, 1890	0.00	0.00	0.42	1.48	1.25	21.61
****Harpinia pectinata* Sars, 1891	2.08	0.00	1.78	0.14	10.52	0.00
***Apseudopsis latreillii* (Milne-Edwards, 1828)	31.67	40.00	13.54	61.79	3.37	2.48
**Iphinoe douniae* Ledoyer, 1965	16.67	1.67	0.39	1.53	0.00	1.00
***Eurydice pulchra* Leach, 1815	0.42	0.00	1.96	6.44	2.33	1.48

Table 5. Spearman's rank correlation values among environmental parameters (r; bold values significant at P < 0.05). See Table 3 for abbreviations of the parameters.

	Depth	**SST**	**NBT**	**SSS**	**NBS**	**SSD**	**NBD**	**Gravel**	**Sand**	**Silt**	**Clay**	**Mud**	**$CaCO_3$**	**TOC**
Depth	1.000	0.054	**–0.877**	0.180	–0.294	0.021	**0.857**	0.154	**–0.763**	**0.652**	**0.594**	**0.705**	**–0.385**	**0.430**
SST		1.000	0.224	**0.476**	0.194	**–0.758**	–0.214	–0.137	–0.063	0.099	0.093	0.091	–0.096	0.227
NBT			1.000	–0.018	**0.471**	–0.256	**–0.976**	–0.053	**0.631**	**–0.445**	**–0.379**	**–0.492**	0.162	–0.232
SSS				1.000	–0.040	0.070	–0.006	0.013	–0.150	0.030	**0.465**	0.178	–0.231	–0.045
NBS					1.000	–0.079	**–0.405**	**–0.357**	0.215	0.031	–0.171	–0.039	–0.125	–0.252
SSD						1.000	0.211	0.045	0.052	–0.143	–0.179	–0.124	0.039	–0.166
NBD							1.000	0.076	**–0.610**	**0.424**	**0.368**	**0.476**	–0.121	0.215
Gravel								1.000	0.000	–0.231	–0.019	–0.194	**0.280**	0.133
Sand									1.000	**–0.895**	**–0.772**	**–0.932**	**0.563**	**–0.354**
Silt										1.000	0.701	0.967	–0.697	0.375
Clay											1.000	**0.821**	**–0.533**	**0.359**
Mud												1.000	**–0.694**	**0.363**
$CaCO_3$													1.000	**–0.327**
TOC														1.000

[Bate, 1857]), and 1 cumacean (*Iphinoe douniae* Ledoyer, 1965) were the contributor species at 10 m, whereas all species, apart from *Upogebia* sp., were more dominant in F–M (most of them in May) than in A–N (Table 4). Amphipods and cumaceans were most abundant in May, and decapods in February and August (Table 4). The tanaidacean *Apseudopsis latreillii* and the isopod *Eurydice pulchra*, which mostly contributed in the intermediate zone (25–100 m; a shallow subentity), were abundant in August (Figure 2; Table 4). Four amphipods were discriminating species of the outer shelf: *Cheirocratus sundevalli* (Rathke, 1843) and *H. pectinata* for F–M (more abundant in May), and *E. elongata* and *H. antennaria* for A–N (more abundant in November) (Table 4).

4. Discussion

Environmental gradients could affect the biodiversity patterns of benthic organisms both directly and indirectly. Those are classified as resources (chemicals, nutrients, energy consumption), and direct (grain size of sediment and temperature) and indirect gradients as a synergetic effect of both depth and latitude (Meynard and Quinn, 2007). Here, the depth drives the direct gradients and resources' effect for the pattern. The species composition and density distribution of the macrobenthic crustaceans in Mersin Bay of the Cilician shelf were primarily determined by bottom depth and depth-related sedimentary parameters, and secondarily by sea surface temperature. According to Gray (2002), nutrients, temperature, and sediment grain size play dominant roles in regional benthic richness. The number of crustacean species peaked at 10 m and 75–100 m, abundance at 10 and 50 m, and biomass at 25 m. Crustacean species richness slightly decreases with depth in the eastern (Karakassis and Eleftheriou, 1997; Tselepides et al., 2000) and western (Grèmare et al., 1998) Mediterranean Sea. Here, species such as the decapods *D. pugilator* and *Upogebia* sp.; the amphipods *A. brevicornis*, *Medicorophium* sp., *E. punctatus*, *C. sundevalli*, *H. pectinata, E. elongata*, and *H. antennaria*; the cumacean *I. douniae*; the tanaidacean *A. latreillii*; and the isopod *E. pulchra* showed great changes in density through the year. The main population of *D. pugilator* was primarily found at shallow depths where the sediments were mostly fine sand (Mutlu and Ergev, 2010). Occasionally, this species appears in small numbers at greater depths (Mutlu and Ergev, 2008). On the other hand, *A. latreillii* was observed at a depth greater than 20 m in a western Mediterranean site (Tyrrhenian Sea) and occurred most abundantly in December (Tomassetti et al., 2009). Abundance of *Harpinia* spp. increased from 15 ind 100 m^{-2} in autumn and 47 ind 100 m^{-2} in winter and spring to 132 ind 100 m^{-2} in summer on coastal muddy bottoms (40–80 m deep) of the southern Tyrrhenian Sea, whereas abundance of *E. elongata* was very low throughout the year (Fanelli et al., 2009). In the present study, mean crustacean abundance doubled in summer as compared with that in winter, and maximum mean crustacean abundance (200 ind m^{-2}) was found at depths of 10 and 50 m.

Crustacean species, mostly amphipods and tanaidaceans, showed seasonal dynamics across the bottom depth gradient of the shelf. The temperature-dependent life cycle and reproductive strategies of the species determine seasonal changes in density fluctuations that explain the structure of the whole assemblage (Dauvin et al., 1994; Cunha et al., 1999; Moreira et al., 2008). Furthermore, some species show differences in swimming activity, mostly in spring–summer, devoted to a reproductive effort that is responsible for seasonal differences in abundance and presence (Dauvin et al., 1994). The most abundant crustacean species of the Cilician Basin were *A. latreillii* and *A. brevicornis*, similar to the findings of Bogdanos and Satsmadjis (1983) for the Aegean Sea. *A. brevicornis* showed increased densities in spring and *A. latreillii* in summer. *E. pulchra* had its maximum density within the period between February and November from Hendaya Beach, southern Bay of Biscay (San Vicente and Sorbe, 2001). These seasonal changes were generally correlated with reproductive and recruitment processes, and were affected by the abundance of amphipods (such as *A. brevicornis)* during springtime (Occhipinti-Ambrogi et al., 2005). The western Mediterranean Sea had high densities of crustaceans in summer (Harriague et al., 2006) and at 30 m (Grèmare et al., 1998).

Bathymetrically described crustacean communities were correlated with seasonal factors over the shelf. Subsequent to depth (Karakassis and Eleftheriou, 1997), grain size and organic content of the sediment are considered the second most significant characteristics (Gray, 1981; Harriague et al., 2007). Seasonal variation in environmental variables that change seasonally may also be related to depth (McArthur et al., 2009). Although the seasonal variation was smaller below 50 m than above 50 m, the deep-water crustacean assemblages that could be dependent on seasonal biological productivity diminishing later in the year were more clearly distinguished by the seasons than those of shallow waters were. Additionally, the sediment, hydrographical, and biological variables that are depth-related are more likely to be the controlling factors than depth itself (Gray, 1981; Karakassis and Eleftheriou, 1997). In the present study, certain species played an important role in structuring the crustacean community by depth and season. The tanaidacean *Apseudes* sp. was found to be restricted to inner-shelf sites of the South Atlantic Bight (Wenner et al., 1984). The isopod *E. pulchra* was one of the macroinvertebrates showing higher densities at the beach of De Panne, Belgium (Degraer et al., 1999) and was found within 10 m of the shelf in the Bay of Biscay (Martínez and Adarraga, 2001). In the present study, *A. brevicornis* and *H. antennaria* were observed at 40–75 m and 75–165 m, respectively (Martínez and Adarraga, 2001). Karakassis and Eleftheriou (1997) studied the 4 Cretan zones (130–190 m, 130–160 m, intermediate zone of 70–130 m, and shallow zone) of macrofaunal patchiness and discussed 2 deep zones that overlapped due to heterogeneity of sediment characteristics among the deep zones. Tselepides et al. (2000) distinguished the macrofauna of 40 m and 100–200 m depths from other deeper clusters of the Cretan shelf. Martínez and Adarraga (2001) determined shallow zone (5–50 m), central shelf (75–125 m), and deep shelf (160–225 m) assemblages on the shelf of Bay of Biscay. A slight positive correlation was found between the crustacean distribution and TOC in the area of study, since the study region is one of the most oligotrophic areas (Yılmaz and Tuğrul, 1998). The biodiversity pattern of the macrofauna is best explained with multienvironmental variables under undisturbed conditions (Dauer et al., 2000). The mean abundance and number of species showed a significant negative correlation with the depth, but a positive correlation with the TOC content of the sediment (Kroncke et al., 2003).

In conclusion, crustacean diversity was moderately good (90 species) for an oligotrophic region of the Cilician Basin according to the findings for the western Mediterranean Sea: e.g., 119 crustacean species in the Tyrrhenian Sea (Scipione et al., 2005), 149 in Catalan coasts (Munilla and Vicenta, 2005), 60 decapods in Spanish coasts (Garcia-Munoz et. al., 2008), and 237 species in the English Channel (Dauvin et al., 2000). The average and biomass were also very low compared with those found in other regions of the Mediterranean Sea. The crustacean communities in the area varied primarily according to depth and depth-related sedimentary parameters, and secondarily according to the sea surface temperature. Two major crustacean assemblages occurred, the first in shallow water (10, 25–100 m, corresponding to the photic zone) and the second in deep water (150–200 m, corresponding to the aphotic zone).

Acknowledgments
The present study was carried out within the framework of a project (YDABCAG-100Y015) funded by the Scientific and Technological Research Council of Turkey (TÜBİTAK) and includes a portion of the MSc thesis by Mehmet Betil Ergev (2002, IMS-METU, Turkey). We thank Karen Fisher, Evrim Kalkan, Murat Bilecenoğlu, M. Tunca Olguner, and 3 anonymous referees for their valuable comments and correction of the English of the text.

Appendix

Crustacean species showing dominance (D%) and maximum density values (ind m^{-2}) for each sampling season. F: February; M: May; A: August; N: November. The number given after the slash represents depth (m). ND: species not detected at any depth. * is an alien species.

Species/Orders	D%	F	M	A	N
Decapoda					
Aegaeon lacazei (Gourret, 1887)	1.23	10/90	ND	ND	ND
Alpheus glaber (Olivi, 1792)	16.05	20/28–65	10/21, 100–147	10/30–59	10/13–20, 145
Alpheus sp.	18.52	10/25–95	10/60	30/56	20/28
Callianassa sp.	11.11	10/25–35	10/13–21, 147	10/30–55	20/59
Callianassa subterranea (Montagu, 1808)	13.58	20/28	40/40	10/22–24	20/28
Callianassa tyrrhena (Petagna, 1792)	1.23	10/25	ND	ND	ND
Carcinus aestuarii Nardo, 1847	1.23	10/100	ND	ND	ND
Crangon crangon (Linnaeus, 1758)	14.81	40/70	30/21	ND	20/8
Crangon sp.	11.11	10/205	ND	10/13, 56–146	20/28–53
Diogenes pugilator (Roux, 1829)	12.35	60/10	30/13	10/10, 59	ND
Ebalia cranchii Leach, 1817	1.23	ND	ND	ND	10/102
Ebalia tuberosa (Pennant, 1777)	1.23	10/95	ND	ND	ND
Goneplax rhomboides (Linnaeus, 1758)	12.35	10/70	20/8–22	50/24	40/13
Jaxea nocturna Nardo, 1847	1.23	ND	ND	ND	10/150
Leptochela pugnax De Man, 1916	30.87	20/35	30/40	10/30–99	20/23–105
Liocarcinus depurator (Linnaeus, 1758)	2.47	10/6	ND	ND	10/102
Maja crispata Risso, 1827	1.23	ND	ND	ND	10/75
Nephropidae indet.	1.23	ND	ND	10/85–90	ND
Pagurus prideaux Leach, 1815	1.23	ND	ND	ND	10/85
Pandalidae indet.	1.23	ND	ND	ND	10/153

Appendix (continued)

Parapenaeus longirostris (Lucas, 1846)	1.23	ND	10/78	ND	ND
Parthenope sp.	1.23	ND	ND	ND	10/85
Pasiphaea sp.	1.23	ND	10/60	ND	ND
Penaeidae indet.	1.23	ND	ND	ND	10/8
Portunidae indet.	1.23	ND	ND	ND	10/55
Processa edulis (Risso, 1816)	3.7	20/66	20/30	ND	ND
Processa robusta Nouvel & Holthuis, 1957	1.23	ND	ND	ND	40/10
Processa sp.	2.47	10/145	ND	10/59	ND
Upogebia pusilla (Petagna, 1792)	1.23	ND	ND	50/9	ND
Upogebia sp.	7.41	ND	20/8, 31, 104	1290/9	10/27, 145
Amphipoda					
Ampelisca brevicornis (Costa, 1853)	80.25	90/10	650/8	90/9	220/11
Ampelisca diadema (Costa, 1853)	1.23	10/50	ND	ND	ND
Ampelisca sp.	8.64	20/82	20/58	20/145	10/13, 28
Aoridae indet.	7.41	ND	ND	ND	20/150–195
Bathyporeia sp1.	1.23	ND	20/7	ND	ND
Bathyporeia sp2.	1.23	10/6	ND	ND	ND
Ceradocus sp.	1.23	20/145	ND	ND	ND
Cheirocratus sundevalli (Rathke, 1843)	3.7	10/149–153	90/185	ND	ND
Ericthonius punctatus (Bate, 1857)	17.28	140/5	40/11	10/50–87	10/98
Ericthonius sp.	1.23	ND	ND	10/80	ND
Eriopisa elongata (Bruzelius, 1859)	25.93	20/146–200	10/47, 150–201	50/151	60/150
Gammaropsis maculata (Johnston, 1828)	8.64	20/95	20/21–57, 201	50/10	10/150
Harpinia antennaria Meinert, 1890	23.46	ND	20/145	30/146–195	80/145
Harpinia pectinata Sars, 1891	20.99	20/97–149	50/185–195	10/48	ND
Harpinia sp.	1.23	ND	ND	ND	10/96
Hippomedon sp.	2.47	10/82	ND	10/26	ND
Ischyrocerus sp.	1.23	10/56	ND	ND	ND
Jassa falcata (Montagu, 1808)	1.23	10/82	ND	ND	ND
Lembos sp.	2.47	ND	ND	10/145	10/75
Leucothoe lilljeborgi Boeck, 1861	13.58	ND	ND	20/30–79	50/13
Leucothoe procera Bate, 1857	3.7	20/8	20/8	ND	ND
Leucothoe sp.	2.47	ND	ND	ND	10/13, 75
Leucothoe spinicarpa (Abildgaard, 1789)	2.47	10/50	10/31	ND	ND
Lysianassidae indet.	2.47	10/10	10/97	ND	ND
Medicorophium sp.	24.69	10/30–100	70/8	30/48	30/86
Megaluropus agilis Hoeck, 1889	3.7	20/10	30/7	ND	ND
Melita sp.	1.23	30/153	ND	ND	ND
Oedicerotidae indet.	1.23	ND	ND	10/10	ND
Paraphoxus oculatus (Sars, 1879)	1.23	60/149–153	ND	ND	ND

Appendix (continued)

Perioculodes longimanus (Bate & Westwood, 1868)	8.64	40/6	ND	ND	60/13
Phtisica marina Slabber, 1769	9.88	10/8, 30–90	10/7–13	ND	ND
Socarnes erythrophthalmus Robertson, 1892	3.7	ND	ND	ND	10/20, 75
Socarnes filicornis (Heller, 1866)	2.47	10/82	10/90	ND	ND
Synchelidium maculatum Stebbing, 1906	8.64	10/10	20/7–13	ND	70/11
Synchelidium sp.	1.23	ND	ND	10/90	ND
Tryphosella sp.	1.23	10/8	ND	ND	ND
Urothoe poseidonis Reibish, 1905	1.23	10/8–10	ND	ND	ND
Urothoe sp.	1.23	ND	10/145	ND	ND
Tanaidacea					
Apseudopsis latreillii (Milne-Edwards, 1828)	60.49	210/55	210/60	1590/50	380/8
Apseudes sp.	1.23	10/149–156	ND	ND	ND
Leptochelia savignyi (Kroyer, 1842)	2.47	ND	ND	20/10	ND
Cumacea					
Bodotria pulchella (Sars, 1878)	1.23	10/10	ND	ND	ND
Bodotria sp.	1.23	ND	ND	ND	10/177
Campylaspis glabra Sars, 1878	1.23	ND	ND	ND	10/102
Cumella (Cumella) pygmaea G.O. Sars, 1865	1.23	ND	10/79	ND	ND
Diastylis rugosa Sars, 1865	1.23	ND	10/77	ND	ND
Iphinoe douniae Ledoyer, 1965	25.93	20/10	70/8–13	20/79	10/10, 53–105, 200
Leucon (Leucon) mediterraneus Sars, 1878	3.7	ND	ND	20/80	20/10
Isopoda					
Anthura gracilis (Montagu, 1808)	4.94	ND	10/145	10/55, 195	20/55
Eurydice pulchra Leach, 1815	34.57	30/35	10/8, 77–195	100/50	20/27–90
Eurydice sp.	2.47	10/36, 180	ND	ND	ND
Eurydice spinigera Hansen, 1890	3.7	10/50–106	ND	ND	ND
Gnathia maxillaris (Montagu, 1804)	4.94	ND	10/90	ND	10/53–75
Gnathia sp.	6.17	10/100	ND	10/79–100	10/86
Joeropsis brevicornis Koehler, 1885	1.23	10/180	ND	ND	ND
Mysida					
Gastrosaccus sanctus (van Beneden, 1861)	7.41	20/65–66	10/11, 195	ND	20/8
Nebaliacea					
Nebalia sp.	1.23	ND	ND	10/9	ND
Stomatopoda					
Clorida albolitura Ahyong & Naiyanetr, 2000	1.23	ND	ND	10/22	ND
Squilla mantis (Linnaeus, 1758)	1.23	ND	10/14	ND	ND
Ostracoda					
Euphilomedes sp.	11.11	10/100	ND	20/104	30/102

References

Anderson, M.J. 2001. A new method for non-parametric multivariate analysis of variance. Austral. Ecol. 26(1): 32–46.

Ateş, A.S., Özdilek, Ş.Y., Özcan, T. and Kontaş, T. 2007. On the presence of the brachyuran crab *Macropodia tenuirostris* (Crustacea: Decapoda: Majidae) on the Levantine coast of Turkey. Mar. Biodivers. Rec. 1: e79.

Bakir, K., Sezgin, M. and Katağan, T. 2007. Contribution to the knowledge of alien amphipods off the Turkish coast: *Gammaropsis togoensis* (Schellenberg, 1925). Aquat. Invasions 2(1): 80–82.

Bogdanos, C. and Satsmadjis, J. 1983. The macrozoobenthos of an Aegean embayment. Thalasographica 6: 77–105.

Çinar, M.E., Bilecenoğlu, M., Öztürk, B., Katağan, T., Yokeş, M.B., Aysel, V., Dağlı, E., Açık, S., Özcan, T. and Erdoğan H. 2011. An updated review of alien species on the coasts of Turkey. Mediterr. Mar. Sci. 12(2): 257–315.

Çinar, M.E., Katağan, T., Koçak, F., Öztürk, B., Ergen, Z., Kocatas, A., Önen, M., Kırkım, F., Bakir, K., Kurt, G., Dağli, E., Açik, S., Doğan, A. and Özcan, T. 2008. Faunal assemblages of the mussel *Mytilus galloprovincialis* in and around Alsancak Harbour (Izmir Bay, eastern Mediterranean) with special emphasis on alien species. J. Marine Syst. 71(1–2): 1–17.

Çinar, M.E., Katagan, T., Öztürk, B., Egemen, Ö., Ergen, Z., Kocatas, A., Önen, M., Kirkim, F., Bakir, K., Kurt, G., Dagli, E., Kaymakçi, A., Açik, S., Dogan, A. and Özcan, T. 2006. Temporal changes of soft bottom zoobenthic communities in and around Alsancak Harbor (Izmir Bay, Aegean Sea), with special attention to the autecology of exotic species. Mar. Ecol.. 27(3): 229–246.

Coleman, N., Cuff, W., Moverley, J., Gason, A.S.H. and Heislers, S. 2007. Depth, sediment type, biogeography and high species richness in shallow-water benthos. Mar. Freshwater Res. 58(3): 293–305.

Coma, R., Ribes, M., Gili, J.M. and Zabala, M. 2000. Seasonality in coastal benthic ecosystems. Trends Ecol. Evol. 15(11): 448–453.

Conides, A., Bogdanos, C. and Diapoulis, A. 1999. Seasonal ecological variations of phyto- and zoobenthic communities in the south of Nisyros Island, Greece. Environmentalist 19(2): 109–127.

Cunha, M.R., Sorbe, J.C. and Moreira, M.H. 1999. Spatial and seasonal changes of brackish peracaridan assemblages and their relation to some environmental variables in two tidal channels of the Ria de Aveiro (NW Portugal). Mar. Ecol. Prog. Ser. 190: 69–87.

Dauer, D.M., Ranasinghe, J.A. and Weisberg, S.B. 2000. Relationships between benthic community condition, water quality, sediment quality, nutrient loads, and land use patterns in Chesapeake Bay. Estuaries 23(1): 80–96.

Dauvin, J.C., Iglesias, A. and Lorgeré, J.C. 1994. Circalittoral suprabenthic coarse sand community from the Western English Channel. J. Mar. Biol. Assoc. U.K. 74(3): 543–562.

Dauvin, J.C., Thiébaut, E., Gomez Gesteira, J.L., Ghertsos, K., Gentil, F., Ropert, M. and Sylvand, B. 2004. Spatial structure of a subtidal macrobenthic community in the Bay of Veys (western Bay of Seine, English Channel). J. Exp. Mar. Biol. Ecol. 307(2): 217–235.

Dauvin, J.C., Vallet, C., Mouny, P. and Zouhiri, S. 2000. Main characteristics of the boundary layer macrofauna in the English Channel. Hydrobiologia 426: 139–156.

Degraer, S., Mouton, I., De Neve, L. and Vincx, M. 1999. Community structure and intertidal zonation of the macrobenthos on a macrotidal, ultra-dissipative sandy beach: summer-winter comparison. Estuaries 22(38): 742–752.

Doğan, A., Özcan, T., Bakir, K. and Katagan, T. 2008. Crustacea Decapoda associated with *Brachidontes pharaonis* (P. Fischer, 1870) (Mollusca, Bivalvia) beds from the Levantine coasts of Turkey. Crustaceana 81(11): 1357–1366.

Ediger, V., Evang, G. and Ergin, M. 1997. Recent surficial shelf sediments of the Cilician Basin (Turkey), northeastern Mediterranean. Cont. Shelf. Res. 17: 1659–1677.

Ergin, M. 1996. Subaerially exposed Late-Quaternary basinal shelf of the inner Mersin Bay, Eastern Mediterranean: paleoenvironmental evidence. Geo-Mar. Lett. 16: 95–100.

Fanelli, E., Cartes, J.E., Badalamenti, F., Rumolo, P. and Sprovieri M. 2009. Trophodynamics of suprabenthic fauna on coastal muddy bottoms of the southern Tyrrhenian Sea (western Mediterranean). J. Sea Res. 61(3): 174–187.

Fishelson, L. 2000. Marine animal assemblages along the littoral of the Israeli Mediterranean seashore: the Red-Mediterranean Seas communities of species. Ital. J. Zool. 67(4): 393–415.

Galil, B.S. and Lewinsohn, C. 1981. Macrobenthic communities of the Eastern Mediterranean continental shelf. Mar. Ecol. 2: 343–352.

García Muñoz, J.E., Manjón-Cabeza, M.E. and García Raso, J.E. 2008. Decapod crustacean assemblages from littoral bottoms of the Alborán Sea (Spain, west Mediterranean Sea): spatial and temporal variability. Sci. Mar. 72(3): 437–449.

Ghertsos, K., Luczak, C., Dewarumez, J.M. and Dauvin, J.C. 2000. Influence of spatial scales of observation on temporal change in diversity and trophic structure of fine-sand communities from the English Channel and the southern North Sea. ICES J. Mar. Sci. 57(5): 1481–1487.

Gray, J.S. 1981. The Ecology of Marine Sediments: An Introduction to the Structure and Function of Benthic Communities. Cambridge University Press, London.

Gray, J.S. 2002. Species richness of marine soft sediments. Mar. Ecol. Prog. Ser. 244: 285–297.

Grèmare, A., Amouroux, G. and Vétion, G. 1998. Long-term comparison of macrobenthos within the soft bottoms of the Bay of Banyuls-sur-mer (northwestern Mediterranean Sea). J. Sea Res. 40(3–4): 281–302.

Harriague, A.C., Albertelli, G., Bonomi, A., Fabiano, M. and Zunini-Sertorio, T. 2007. Pelagic–benthic coupling in a subtidal system of the North-Western Mediterranean. Chem. Ecol. 23(3): 263–277.

Harriague, A.C., Bianchi, C.N. and Albertelli, G. 2006. Soft-bottom macrobenthic community composition and biomass in a *Posidonia oceanica* meadow in the Ligurian Sea (NW Mediterranean). Estuar. Coast. Shelf Sci. 70(1–2): 251–258.

Jones, D.L. 2002. User Manual for FATHOM: A MATLAB Toolbox for Multivariate Ecological and Oceanographic Data Analysis. Cooperative Institute for Marine and Atmospheric Science, University of Miami–RSMAS, Miami.

Karakassis, I. and Eleftheriou, A. 1997. The continental shelf of Crete: structure of macrobenthic communities. Mar. Ecol. Prog. Ser. 160: 185–196.

Kroncke, I., Turkay, M. and Fiege, D. 2003. Macrofauna communities in the Eastern Mediterranean deep sea. Marine Ecology 24(3): 193–216.

Labropoulou, M. and Kostikas, I. 1999. Patterns of resource use in deep-water decapods. Mar. Ecol. Prog. Ser. 184: 171–182.

Martínez, J. and Adarraga, I. 2001. Distribución batimétrica de comunidades macrobentónicas de sustrato blando en la plataforma continental de Guipúzcoa (golfo de Vizcaya). Bol. Inst. Esp. Oceanogr. 17(1): 33–48.

McArthur, M.A., Brooke, B., Przeslawski, R., Ryan, D.A., Lucieer, V.L., Nichol, S., McCallum, A.W., Mellin, C., Cresswell, I.D. and Radke, L.C. 2009. A Review of Surrogates for Marine Benthic Biodiversity. Geoscience Australia, Canberra.

Meynard, C.N. and Quinn, J.F. 2007. Predicting species distributions: a critical comparison of the most common statistical models using artificial species. J. Biogeogr. 34(8): 1455–1469.

Moreira, J., Gestoso, L. and Troncoso, J.S. 2008. Diversity and temporal variation of peracarid fauna (Crustacea: Peracarida) in the shallow subtidal of a sandy beach: Playa América (Galicia, NW Spain). Mar. Ecol. 29(S1): 12–18.

Munilla, T. and San Vicente, C. 2005. Suprabenthic biodiversity of Catalan beaches (NW Mediterranean). Acta Oecol. 2: 81–91

Mutlu, E., Çinar, M.E. and Ergev, M.B. 2010. Distribution of soft-bottom polychaetes of the Levantine coast of Turkey, eastern Mediterranean Sea. J. Marine Syst. 79(1–2): 23–35.

Mutlu, E. and Ergev, M.B. 2008. Spatio-temporal distribution of soft-bottom epibenthic fauna on the Cilician shelf (Turkey), Mediterranean Sea. Rev. Biol. Trop. 56(4): 1919–1946.

Mutlu, E. and Ergev, M.B. 2010. Temporal variability of density and diverse shell occupancy of *Diogenes pugilator* on a sandy bottom of the Levantine Sea and their biometrical relationships. Cah. Biol. Mar. 51(1): 55–67.

Mutlu, E. and Ergev, M.B. 2012. Distribution of soft-bottom mollusks (Mollusca) in Mersin Bay (eastern Mediterranean Sea). Turk. J. Zool. 36(4): 430–446.

Nybakken, J.W. 1982. Marine Biology: An Ecological Approach. Harper and Row, New York.

Occhipinti-Ambrogi, A., Savini, D. and Forni, G. 2005. Macrobenthos community structural changes off Cesenatico coast (Emilia Romagna, Northern Adriatic), a six-year monitoring programme. Sci. Total Environ. 353(1–3): 317–328.

Özcan, T., Galil, B.S., Bakır, K. and Katağan, T. 2006. The first record of the banana prawn *Fenneropenaeus merguiensis* (De Man, 1888) (Crustacea: Decapoda: Penaeidae) from the Mediterranean Sea. Aquat. Invasions 1(4): 286–288.

Özsoy, E., Hecht, A., Ünlüata, Ü., Brenner, S., Sur, H.I., Bishop, J., Latif, M.A., Rozentraub, Z. and Oğuz, T. 1993. A synthesis of the Levantine Basin circulation and hydrography, 1985-1990. Deep-Sea Research Part II, 40(6): 1075–1119.

Papazacharias, A., Koukouras, A., Kevrekidis, T. and Voultsiadou, E. 1998. Infra- and circalittoral soft substratum macrofaunal assemblages of Kavala Gulf (Aegean Sea). Int. Rev. Hydrobiol. 83(5–6): 461–477.

Rhoads, D.C. and Young, D.K. 1970. The influence of deposit-feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 28(2): 150–178.

San Vicente, C.S. and Sorbe, J.C. 2001. Temporal changes in the structure of the suprabenthic community from Hendaya Beach (southern Bay of Biscay): a comparison with a northwestern Mediterranean beach community. Bol. Inst. Esp. Oceanogr. 17(1): 107–120.

ter Braak, C.J.F. and Smilauer, P. 2002. CANOCO 4.5. CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, New York.

Tom, M. and Galil, B. 1991. The macrobenthic associations of Haifa Bay, Mediterranean coast of Israel. Marine Ecology 12(1): 75–86.

Tomassetti, P., Persia, E., Mercatali, I., Vani, D., Marussso, V. and Porrello, S. 2009. Effects of mariculture on macrobenthic assemblages in a western Mediterranean site. Mar. Pollut. Bull. 58(4): 533–541.

Tselepides, A., Papadopoulou, K.N., Podaras, D., Plaiti, W. and Koutsoubas, D. 2000. Macrobenthic community structure over the continental margin of Crete (South Aegean Sea, NE Mediterranean). Prog. Oceanogr. 46(2–4): 401–428.

Scipione, M., Lattanzi, B.L., Tomassetti, P., Chimenz Gusso, C., Maggiore, F., Mriniello, L., Cironi, R., Taramelli, E. 2005. Biodiversity and zonation patterns of crustacean peracarids and decapods of coastal soft-bottom assemblages (central Tyrrhenian Sea, Italy). Vie Milieu 55(2): 143–161.

Wenner, L., Hinde, P., Knott, D.M. and Van Dolah, R.F. 1984. A temporal and spatial study of invertebrate communities associated with hard-bottom habitats in the south Atlantic Bight. NOAA Tech. Rep. NMFS 18: 1–104.

Yılmaz, A. and Tuğrul, S. 1998. The effect of cold- and warm-core eddies and the distribution and stoichiometry of dissolved nutrients in the northeastern Mediterranean. J. Marine Syst. 16(3–4): 253–268.

Yokes, M.B., Karhan, S.Ü., Okus, E., Yüksek, A., Aslan-Yilmaz, A., Yilmaz, I.N., Demirel, N., Demir, V. and Galil, B.S. 2007. Alien crustacean decapods from the Aegean coast of Turkey. Aquat. Invasions 2(3): 162–168.