ASPECTS OF DECAPOD CRUSTACEAN ASSEMBLAGES FROM SOFT BOTTOMS SUBMITTED TO STRONG HYDRODYNAMIC CONDITIONS: AN EXAMPLE FROM CANAKKALE STRAIT (TURKISH STRAIT SYSTEM)

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ABSTRACT

This study deals with the structure of decapod crustacean assemblages and their relationships with biotic and abiotic conditions in Canakkale Strait in 2006 and 2007. A total of 45 Decapod species were found, of which one species (*Calliax lobata*) is recorded for the first time from Turkish waters, four species are new for the Turkish Strait System and 11 species for the Canakkale Strait. Number of species, abundance, richness and biodiversity were negatively correlated to sand percentage and positively correlated to TOC values. In addition, ABC analysis showed that Canakkale Strait is subjected to natural stress. Hydrodynamic conditions have been recognised as the most important natural stress factor. While seasonal changes were not statistically significant, differences in biomass and species number were statistically important among stations, clearly separating eastern from western costs. Spring could be considered as decapods reproductive period in Canakkale Strait. Four different feeding types were distinguished, carnivors being the dominant one in the area. *Athanas nitescens* and *Pisidia blutelii* were the most important species, representing 62.6 % of the total abundance. These dominant species were significantly correlated with different sediment variables (percentage of sand, medium gravel and fine gravel). Different feeding mode and niche partitioning are advantageous for survival in such a harsh environment. No alien decapods were found in the study area, but during warm seasons, the presence of the invasive macroalga *Caulerpa racemosa* in the southeastern part of Canakkale Strait could favour some scavenger decapod species.

KEYWORDS: Decapoda, soft bottoms, quantitative distribution, Canakkale Strait, Turkish Strait System

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1. INTRODUCTION

Canakkale Strait is one of the two straits in the Turkish Straits System and connects the Mediterranean Sea (Aegean basin) with the Sea of Marmara, which further communicates with the Black Sea through the Istanbul Strait at its other extremity. A very dense maritime traffic occurs in all Turkish Straits, even though they are difficult to navigate. Totally, 49,453 vessels of 667,412,661 gross tons passed through the Canakkale Strait during 2009. The dense maritime traffic is severely affecting the environment. Accidents, garbage and used oil dumping, ballast water and waste water discharges contribute to a great extent to marine pollution [1] On the other hand, Straits play an important role as a biological corridor between the Mediterranean and the Black Sea, and act as an acclimatization zone for the Mediterranean species [2].

Decapod crustaceans are an important ecological component in the Mediterranean Sea, and constitute a key taxon linking lower and higher trophic level [3, 4]. Despite of its biogeographical interest, the Canakkale Strait is one of the most poorly studied areas in the Mediterranean Sea as regards to decapod assemblages [5-13]. Moreover, most of these studies focus on decapod taxonomy, without any investigation on ecological requirements and/or adaptations to the peculiar environmental conditions of the Strait. It is however undeniable that physical and chemical processes within sediments affect the benthic infaunal activity [14], and spatial and temporal variation of species is important for the comprehension of interactions between biotic and abiotic environmental factors [15, 16].

The objectives of the present study were 1) to examine decapod biodiversity in coastal and offshore soft bottoms, 2) to illustrate the seasonal dynamics of decapod fauna and 3) to correlate temporal variation with abiotic parameters such as hydrodynamism and water circulation.

2. MATERIALS AND METHODS

2.1. Study area

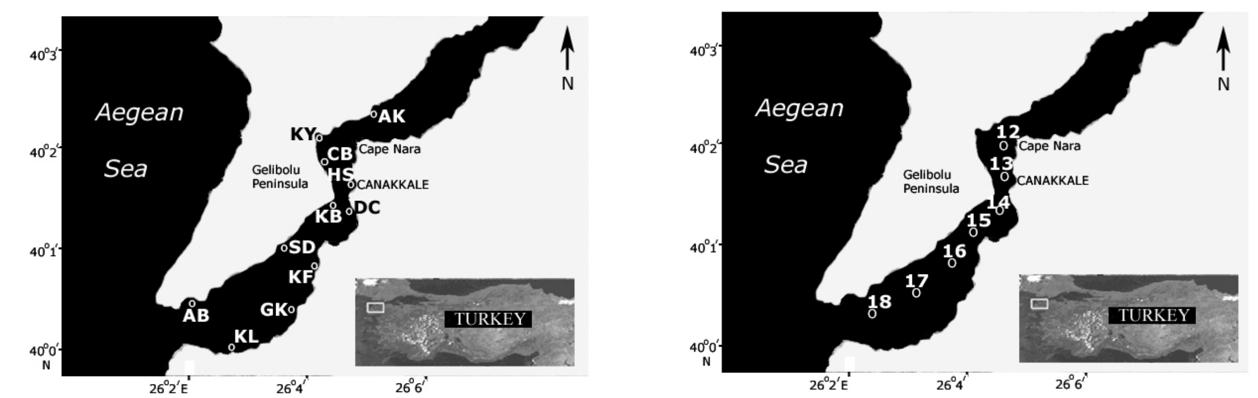
Samplings were performed along the southern part of the Canakkale Strait (Figure 1a). It has an approximate length of 70 km, and its average width and depth are of 3.5 km and 55 m respectively. Water masses traversing the Strait outline two distinct layers, of Black Sea and Mediterranean origin respectively: the upper layer water mass enters into the Canakkale Strait from the Sea of Marmara. Relatively uniform conditions prevail in the upper half of Canakkale Strait, but at Cape Nara (Figure 1b) the upper layer undergo intense vertical mixing when joining the Aegean Sea water, which results in a thin surface layer of less than 10 m with salinity of 25.0-28.0 psu and variable temperature according to the season. The relatively dense Mediterranean underflow enters into the Canakkale Strait below 10-15 m depth, with salinity of 38.9-39.0 psu and temperature 16-17 ºC [17]. The surface layer in the Canakkale Strait flows towards the Aegean Sea, at speed of 50-200 cm s^{-1}. The bottom layer moves in the opposite direction, towards the Sea of Marmara, with speed of 20-40 cm s^{-1} [18]. Some 1257 km^3 of colder and fresher water flows annually into the Aegean Sea whilst, at the same time, 957 km^3 of the more saline Aegean Sea water enters the Sea of Marmara through the Canakkale Strait [19].

2.2. Sampling design

Soft bottom samples were collected in February, June, September and November 2006 by means of a 0.1 m^2 van Veen grab at 11 stations; six of them were located along the European shelf and the remaining five stations were in the Asian shelf. Samples were collected from depths between 7 and 26 m using the R/V Bilim 1 (Figure 1a). At each station, three replicates were taken for benthic analysis. In addition, seven more stations were sampled by means of van Veen grab, dredge and box-corer along the mid-line of the Canakkale Strait from R/V K. Piri Reis on 22.06.2007 at depths between 30 and 80 m (Figure 1b). Because of the high water hydrodynamism, the sampling gear capacity was very low. Moreover, maritime traffic did not permit long permanence at each station. Therefore only a total of twelve samples were taken in the strait's mid-line, which were used in this study for merely qualitative analyses. However, it must be noticed that the present was the first attempt to obtain benthic samples from this area. Coordinates, depth, used sampling gear as well as sediment types are given in Table 1.

All benthic samples were sieved through a 0.5 mm mesh size sieve and fixed with 4 % formaldehyde-sea water solution. In the laboratory, the decapods were separated under a stereomicroscope and preserved in 70 % ethanol. Specimens were counted and identified, while the total wet weight of each species was estimated by using a balance with 0.0001g sensitivity.

Samples from the two layers (surface and bottom) of the water column were collected with Nansen bottles to perform analyses of oceanographic parameters: Temperature, Salinity, Dissolved Oxygen concentration (DO), pH, Total Dissolved Solids (TDS) and Conductivity were measured on board by using the YSI 556 Multiprobe System. In addition, the visibility (as Secchi disc depth) was determined in each station. Granulometric analyses were performed following Lewis [20]. The percentage of organic carbon was determined spectrophotometrically in sediment samples following the sulphochromic oxidation method [21]. The amount of total nitrogen was measured by the Kjeldahl's method. Unfortunately, due to several technical problems some parameters were missing (bottom water parameters at all stations in summer, DO values of all stations and all parameters at stations KL, GK, DC, HS in winter) [22]. Thus, all statistical analyses were applied to the available abiotic parameters.



a) b)

FIGURE 1 - Map of sites sampled in Canakkale Strait, a) coastal sites (seasonal samplings), b) mid-line area (sampled in June 2007).

TABLE 1 - General characteristics of the study sites.

Station	Lat. (°N)	Long. (°E)	Depth (m)	Gear used	Sediment type
AK	40 13 605	26 25 735	19	van Veen Grab	sandy+muddy+stone
KY	40 12 094	26 22 005	12	van Veen Grab	sandy + detritus (shell)
CB	40 10 395	26 22 082	15	van Veen Grab	*Mytilus galloprovincialis*+sand
KB	40 08 296	2622 436	10	van Veen Grab	sandy + detritus (shell)
SD	40 05 923	26 19 004	15	van Veen Grab	sandy+*Posidonia oceanica*
AB	40 02 960	26 12 544	13	van Veen Grab	sandy+*Posidonia oceanica*
KL	40 00 252	26 14 884	22	van Veen Grab	muddy + *Caulerpa racemosa*
GK	40 02 409	26 20 011	20	van Veen Grab	muddy
KF	40 04 988	26 21 490	18	van Veen Grab	muddy
DC	40 07 783	26 23 786	19	van Veen Grab	sandy
HS	40 09 500	26 24 000	21	van Veen Grab	sandy+ stone
12	40 11 603	26 23 366	60	van Veen Grab, dredge	stone
13	40 10 026	26 23 548	83	van Veen Grab	gravel
14	40 07 663	26 23 145	81	van Veen Grab	sandy
15	40 06 065	26 20 000	40	Box corer, dredge	sandy
16	40 04 333	26 18 668	60	Box corer	muddy
17	40 03 593	26 16 614	69	Box corer	muddy
18	40 01 749	26 13 342	83	Box corer	muddy

2.3. Data analysis

Two statistical methods were used to assess potential spatial and temporal differences in the decapods assemblages, based on the null hypothesis of no difference in the decapods assemblage between stations and seasons.

2.3.1. Univariate analyses

Univariate analyses were applied to characterise the community in terms of relative abundance and diversity. Species number (S), Abundance (N: individuals m^{-2}), Margalef richness index (d), Pielou's evenness index (j) and Shannon-Wiener's diversity index (log_2 base) (H') were calculated for each station and season. The frequency of occurrence (Ci) of the species was calculated to discriminate the most representative species, as described by Soyer [23] and results were evaluated as constant ($1 \geq Ci \geq 0.5$), common ($0.5 > Ci \geq 0.25$) and rare ($Ci < 0.25$) species. Dominance indices (Di, relative total abundance in percentage) and the hierarchical importance of each species (given by the product Ci x Di) were also calculated [24]. The index of dispersion [25] was applied to all data to test the randomness. Each species was assigned to a feeding type after accurate research of available literature on each single species. The feeding types considered include carnivores, suspension feeders, deposit feeders, and omnivores.

Seasonal abundance, biomass and mean individual size of the three most important species were also calculated, to verify check any geographical or temporal trend in their distribution.

Spearman's rank correlation coefficient was used for the whole assemblage as well as for the most important species, in order to determine correlation between biotic and abiotic parameters. Temporal trends at each station were tested using one-way ANOVA.

2.3.2. Multivariate analyses

Multivariate analyses were applied to compare assemblage structures between stations and sampling seasons.

Numerical abundance data were analyzed using cluster and multidimensional scaling (MDS) techniques, based on Bray Curtis similarity, using the PRIMER package ver. 5.0 [26]. Cluster analysis was based on log_{10} (x+1) transformation with the "Taylor's Power Law" method concepts [27]. The one-way ANOSIM permutation test was used to assess significant differences between pre-defined groups of sample sites in the cluster analyses. SIMPER analysis was performed to identify the percentage contribution of each species to the overall similarity/dissimilarity within each species to the groups identified from the cluster analysis. To evaluate levels of disturbance, an Abundance-Biomass Comparison (ABC) was made using seasonal abundance data obtained from each station.

Bray-Curtis dissimilarity matrix of decapods abundance was tested by two-way orthogonal nonparametric (Permutation-based) MANOVA (PERMANOVA software; [28] for differences in decapod assemblages under a model of the stations nested in the seasons.

3. RESULTS

3.1. Analysis of Decapod assemblages structure

A total of 2141 specimens m^{-2} belonging to 45 Decapod species, including 9 Caridea, 11 Anomura, 2 Thalassinidea, and 23 Brachyura, were caught in the study area. Of them, *Calliax lobata* was a new record for Turkish Seas, while *Paguristes syrtensis, Anapagurus chirocanthus, Ebalia edwardsii, Lissa chiragra* were new records for the Turkish Strait System and 11 more species were recorded for the first time from the Canakkale Strait (Table 2). Furthermore, *Goneplax rhomboides* was collected only at station 15, in the mid-line of Canakkale Strait at 40 m of depth. During the study, at station CB in autumn it was impossible to take grabs samples (due to the presence of a *M. galloprovincialis* facies). Additionally, no decapod specimens were obtained at stations KL, GK, KF and DC in winter, at stations KB and GK in spring, at KB in summer, and at AB, KB, KL and DC in autumn.

On the total of 45 identified species, 34 were found along the western coast and 21 along the eastern coast of Canakkale Strait. Only 11 species were present on both coasts, consequently 23 species were present only at stations located on the eastern coast and 10 were present only on the western coast.

Species number (S), abundance (N: number of individuals m^{-2}), species richness (d), diversity (H'), evenness (J) and biomass for each season and station are shown in Figure 2. The highest number of species was found in summer (41 species), followed by autumn with 34 species, and winter with 29 species, while the lowest species number (27 species) was found in spring (Figure 2). Station SD was the richest, with 21 decapod species, while the lowest number was found at stations KB and DC with only three species.

TABLE 2 - List of decapods collected from Canakkale Strait and their abundance (ind m^{-2}). Ni: total abundance; Ci: frequency; Di: dominant species ranked by the average density. * new record for Turkish Seas; **new records for Turkish Strait System; * new records for the Canakkale Strait**

	Western coast						Eastern coast									Mid-line
Species/ Abundance	**AK**	**KY**	**CB**	**KB**	**SD**	**AB**	**KL**	**GK**	**KF**	**DC**	**HS**	**Ni**	**Ci**	**Di**	**CixDi**	
Athanas nitescens (Leach, 1814)	107	202	367	7	97	7	3	10	17	3	73	893	0.26	41.32	10.577	+
Pisidia bluteli (Risso, 1816)		75	357		20						3	455	0.05	21.02	1.004	
Xantho pilipes H. Milne- Edwards, 1867	7	20	17	7	47	7					7	112	0.10	5.25	0.544	
Diogenes pugilator (Roux, 1829)	23	23		3	3					3		55	0.09	2.54	0.259	
Pilumnus spinifer H. Milne- Edwards, 1834***	3	18	22		20							63	0.08	3.05	0.243	+
Pisidia sp.	27	10	30		3	3					10	83	0.06	3.73	0.208	
Alpheus dentipes Guérin-Meneville, 1832 ***	3	28			7							38	0.06	1.86	0.104	+
Eualus cranchii (Leach, 1817)***	7		5		7			3			7	29	0.04	1.02	0.057	
Processa nouveli nouveli Al-Adhub & Willimson, 1975***					7	3		3	10			23	0.04	1.19	0.047	
Pisidia longimana (Risso, 1816)			50								23	73	0.02	2.88	0.046	
Liocarcinus navigator (Herbst, 1794)	3	10			3							16	0.04	0.85	0.034	
Pisidia longicornis (Linnaeus, 1767)***			73									73	0.01	3.73	0.030	
Processa edulis edulis (Risso, 1816)***	10	20										30	0.02	1.19	0.019	
Pagurus forbesii Bell, 1845***							23					23	0.02	1.19	0.019	
Anapagurus chiroacanthus (Liljeborg, 1856)**					7	3						10	0.02	0.51	0.016	
Galathea intermedia Liljeborg, 1851***						3		3			5	11	0.02	0.51	0.012	+
Upogebia pusilla (Petagna, 1792)	3	3							3			9	0.02	0.51	0.012	
Liocarcinus depurator (Linnaeus, 1758)								3		3	3	9	0.02	0.51	0.011	
Liocarcinus corrugatus (Pennant, 1777)***			7			7						14	0.02	0.68	0.011	
Hippolyte leptocerus (Heller, 1863)***	3				3							6	0.02	0.34	0.005	
Cestopagurus timidus (Roux, 1830)***					3	3						6	0.02	0.34	0.005	
Paguristes syrtensis De Saint Laurent, 1971**							3	3				6	0.02	0.34	0.005	+
Ebalia edwardsii Costa, 1838**								3			3	6	0.02	0.34	0.005	
Ilia nucleus (Linnaeus, 1758)						3					3	6	0.02	0.34	0.005	
Pilumnus hirtellus (Linnaeus, 1761)		5				3						8	0.02	0.34	0.005	
Pilumnus sp.			15									15	0.01	0.51	0.004	
Xantho poressa (Olivi, 1792)					10							10	0.01	0.51	0.004	
Galathea squamifera Leach, 1814									7			7	0.01	0.34	0.003	
Lissa chiragra (Fabricius, 1775)**								7				7	0.01	0.34	0.003	
Hippolyte inermis Leach, 1815					3							3	0.01	0.17	0.001	
Hippolyte sp.							3					3	0.01	0.17	0.001	
Processa sp.					3							3	0.01	0.17	0.001	+
Anapagurus sp.								3				3	0.01	0.17	0.001	
Galathea sp.					3							3	0.01	0.17	0.001	
Paguristes eremita (Linnaeus, 1767)					3							3	0.01	0.17	0.001	
Pagurus alatus Fabricius, 1775					3							3	0.01	0.17	0.001	
Calliax lobata (de Gaillande & Lagardére, 1966)*						3						3	0.01	0.17	0.001	
Pagurus sp.					3							3	0.01	0.17	0.001	
Achaeus cranchii Leach, 1817					3							3	0.01	0.17	0.001	
Brachynotus sexdentatus (Risso, 1827)			3									3	0.01	0.17	0.001	
Ethusa mascarone (Herbst, 1785)*								3				3	0.01	0.17	0.001	
Liocarcinus vernalis (Risso, 1816)						3						3	0.01	0.17	0.001	
Macropodia longirostris (Fabricius, 1775)						3						3	0.01	0.17	0.001	
Macropodia sp.								3				3	0.01	0.17	0.001	
Goneplax rhomboides (Linnaeus, 1758)												0	0.00	0.00	0.000	+
No. of specimens m^{-2}	196	414	946	17	258	51	32	44	37	9	137	2141				
No. of species	11	11	11	3	21	13	4	11	4	3	10					
Biomass g m^{-2}	24.65	78.16	60.15	0.72	16.77	11.21	0.5	4.69	0.33	1.02	7.2	2 205.37				

The abundance of decapods was maximum in winter (847 ind m^{-2}) and minimum in spring (295 ind m^{-2}) (Figure 2). Although it was impossible to obtain samples from station CB during autumn, this showed the highest total decapod abundance (946 ind m^{-2}). *Athanas nitescens, Pisidia blutelii* and *P. longimana* were the dominant species at this station.

The highest diversity index (H') was found in winter at SD and in autumn at station GK (H' = 2.6), while the highest evenness (j) value (j = 1) was found in winter at stations AK and AB, in spring at stations SD, AB and KL and in summer at stations KF and DC (Figure 2).

According to ANOVA, the species number was significantly different among stations at $P < 0.05$. Moreover, it was positively correlated with the TOC (Total Organic Carbon) content in the sediment (Spearman rank r= 0.348) and negatively correlated with the percentage of sand (r= -0.3709) at $P < 0.05$. Similarly, decapod abundance decreased with increasing percentage of sand content (r= -0.3371). The diversity index was positively correlated with the TOC content (r= 0.3983) of sediment and negatively correlated with sand percentages (r= -0.369) at $P < 0.05$. Also species richness was positively correlated with TOC (r= 0.4583) and TN (Total Nitrogen) (r= 0.3897), whereas it was negatively correlated with the percent of sand (r= -0.4349). No significant differences were found in temporal and spatial variations in abundance, species richness, diversity and evenness measures.

A total biomass of 205.37 g m^{-2} was measured in the study. The highest total value was obtained in winter (100 g m^{-2}), two times higher than the value obtained in spring which was the second higher biomass (50 g m^{-2}). The highest biomass was measured in winter (70 g m^{-2}) at station KY, where the most important species were *Xantho pilipes* (41 g m^{-2}) and *Pilumnus spinifer* (19 g m^{-2}) (Figure 2). Results of one-way ANOVA revealed significant variations in biomass (p= 0.0361) among stations (P< 0.05), but no seasonal discrimination.

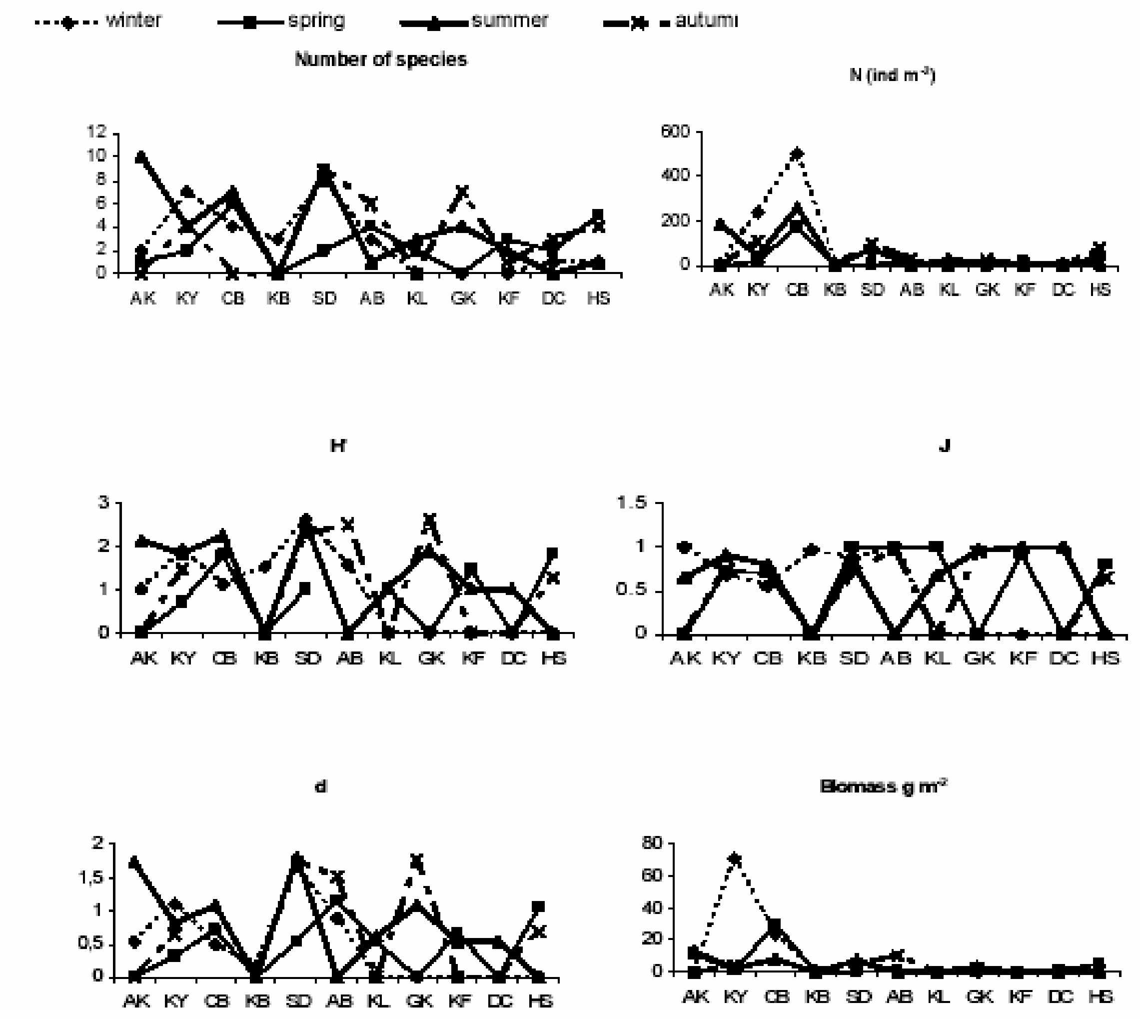


FIGURE 2 - Seasonal qualitative and quantitative distribution of decapod fauna per station in Canakkale Strait (N: Number of individuals m^{-2} , d: Species richness, J: Evenness, H': Diversity, Biomass).

PERMANOVA showed that the decapod distribution interacted significantly with stations and seasons (Table 3).

TABLE 3 - Results of PERMANOVA for decapod assemblages, * = significant (p‹ 0.05)

Source of variation	df	SS	MS	F	P
Season	3	17071.9686	5690.6562	1.5372	0.0880
Station	9	80624.1777	8958.2420	2.4199	0.0010*
Station x Season	27	99951.4812	3701.9067	1.3609	0.0230*
Residual	80	217609.7167	2720.1215		
Total	119	415257.3442			

3.2. Dominant species

As it can be observed in Table 2, in the whole study area constant species (Ci ≥ 0.5) were absent, whereas the only common species (0.5 > Ci ≥ 0.25) was *Athanas nitescens*. It was the most important and characteristic species in the taxocoenosis (values Ci x Di % > 5) responsible for its structure, representing 41.3 % of the total number of specimens (Table 2). Its highest abundance was observed in winter, followed by a sharp decrease in spring, which was succeeded by an important increase in summer (Table 4). The second discriminant species was *Pisidia bluteli* (5 > Ci x Di % > 1). Both of them represent 62.3 % of the total abundance (Table 2).

Among stations, *A. nitescens* had its maximum contribution along the western coast (except for stations KB and AB) and its minimum abundance along the eastern coast (except for station HS) (Table 2). Concerning biomass, the larger brachyuran *Xantho pilipes* prevailed (75 g), followed by *Pilumnus spinifer* (45 g), *Liocarcinus corrugatus* (19 g), *P. bluteli* (18 g) and *Athanas nitescens* (8 g).

TABLE 4 - Seasonal abundance (ind m^{-2}), biomass (g m^{-2}) and mean individual size (g m^{-2}) of *Athanas nitescens*, *Xantho pilipes*, *Pilumnus spinifer*.

		winter	spring	summer	autumn
Total	Abundance	847	295	641	358
	Biomass	99.51	49.87	33.2	22.74
	Mean individual size	0.12	0.17	0.051	0.063
A. nitescens	Abundance	326	86	273	207
	Biomass	3.58	2.13	1.32	1.29
	Mean individual size	0.011	0.025	0.005	0.006
X. pilipes	Abundance	43	7	30	30
	Biomass	50	6	16	3
	Mean individual size	1.16	0.86	0.53	0.1
P. spinifer	Abundance	8	17	12	27
	Biomass	23	16	2	5
	Mean individual size	2.86	0.94	0.17	0.18

Spearman's rank correlation applied between *Athanas nitescens* and *Pisidia blutelii* abundance, biomass and abiotic parameters revealed a slight negative correlation of *A. nitescens* biomass with turbidity and of its abundance with sand percentage, while positive correlation of its abundance with bottom dissolved oxygen and percent of medium gravel was observed (Table 5). Both biomass and abundance of the second dominant species, *P. blutelii*, had a significant positive correlation with the percentages of medium and fine gravel, and negative correlation with bottom temperature, while only its abundance was negatively correlated to surface temperature.

TABLE 5 - Spearman's rank correlation coefficient between biotic and some abiotic parameters. Statistically significant correlations in bold.

		Athanas nitescens		*Pisidia blutelii*	
		Biomass	**N**	**Biomass**	**N**
Turbidity	r_s	**-0.333**	-0.107	-0.273	-0.287
	p-level	0.041	ns	ns	ns
Bottom DO	r_s	0.311	**0.453**	-0.184	-0.293
	p-level	ns	0.045	ns	ns
Surface temp	r_s	-0.297	-0.131	-0.325	**-0.375**
	p-level	ns	ns	ns	0.024
Bottom temp	r_s	-0.273	-0.309	**-0.398**	**-0.466**
	p-level	ns	ns	0.044	0.017
Med. gravel %	r_s	0.202	**0.531**	**0.958**	**0.937**
	p-level	ns	0.001	0.000	0.000
Fine gravel %	r_s	0.068	0.299	**0.7**	**0.679**
	p-level	ns	ns	0.000	0.000
Sand %	r_s	-0.004	**-0.491**	-0.336	-0.317
	p-level	ns	0.003	ns	ns

3.3. Feeding types

Carnivors were the most important feeding type in the area (43 %), folowed by deposit feeders (31%) and suspension feeders (20%), while omnivores were represented only for 6%. Observing Figure 3 carnivors and deposit feeders were present in all stations, ranging respectively from 33 to 91 % and 9 to 39 %. Suspension feeders, while dominant at station CB, showed very low percentages or were absent from other stations. Omnivors, on the contrary, were absent only from station CB, even though showing the lowest total percentage.

Cluster analysis performed on the total abundance of each feeding group per station resulted in two different groups (Figure 4). The first group includes stations HS, SD, KY, AK at similarity level approximately 90%, joined by CB at similarity level higher than 80%. These stations where located on the eastern coast (except HS) northward of Canakkale Strait and had high abundance of all feeding type. The second group's stations were characterized by the absence of suspension feeders (except station KF)

3.4. Multivariate patterns of assemblage structure

Based on Bray-Curtis similarity, three major groups of stations can be recognized, subdivided in subgroups of similarity. The density of *Athanas nitescens* is most responsible for the similarity of groups. The six stations (AB, SD, AK, KY, CB, HS) characterised by the highest abundance, form the group I, with average similarity 41.57. Except for HS, all these stations are located on the west coast of Canakkale Strait. The highest similarity

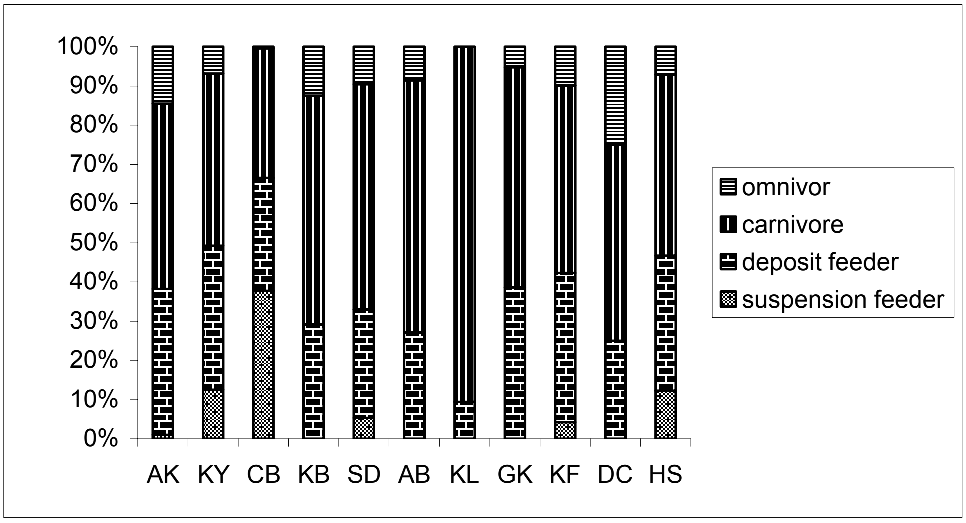


FIGURE 3 - Relative contribution of each feeding type in the sampling stations

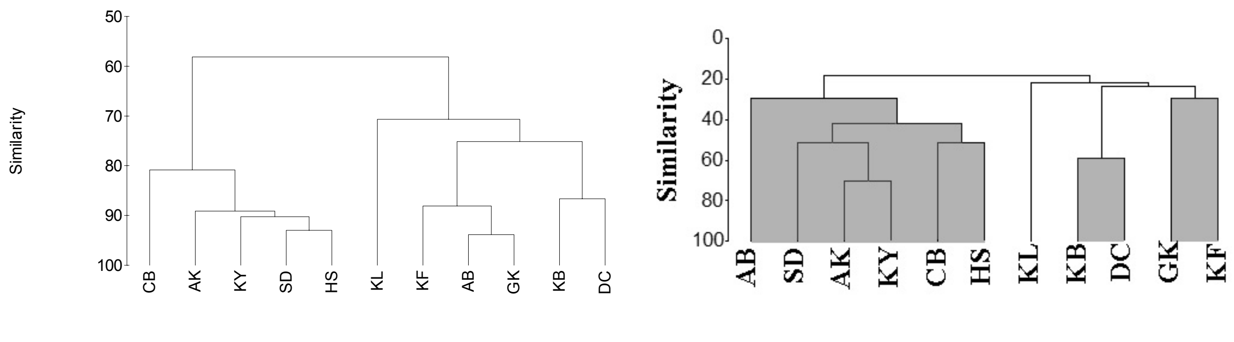


FIGURE 4 - Cluster analyses according to the feeding type (a) and abundance (ind m^{-2}) (b).

value (59%) was estimated within group II (Stations KB and DC), with sandy substrate, both located just below Cape Nara (Figure 2), where mixing of Black Sea and Aegean Sea waters occurs. Group III includes stations GK and KF, with muddy substrate, both located on the east coast of Canakkale Strait. Station KL showed the highest dissimilarity. While no decapods were found during winter and autumn from KL, three specimens of *Pagurus forbesii* and *Pagurus srytensis* were obtained at spring and twenty specimens of *P. forbesii* and three specimens of *Athanas nitescens* and *Hippolyte* sp. were obtained in summer, justifying the high dissimilarity showed by this station.

Results of one-way ANOSIM and SIMPER analysis applied to the total abundance of each species among sampling stations are shown in Table 6. ANOSIM detected a significant difference ($P < 0.005$) between group I and group III, and between group I and KL. Differences in abundance and biomass justify this result: the abundance of all stations belonging to group I ranged between 51 and 946 specimens and their biomass between 7.2 and 78.16 g, meanwhile the abundance of group III was 37 and 44 specimens and their biomass very lower (0.33 g and 4.69 g) (Table 2). According to SIMPER, the most discriminating species was *Pagurus forbesii* (dissimilarity 91.85 %), followed by *Xantho pilipes* (79.35 %) and *Athanas nitescens* (79.35 %).

According to the Abundance-Biomass comparison (ABC) plots (Figure 5), able to determine levels of disturbance, the abundance curve lay above that of biomass, but the curves are closely coincident and cross each other twice (except for summer). Even though W-statistic values were positive (except for winter), they were quite low (0.09-0.15). Thus, even if no severe pollution is affecting decapods assemblages, a moderate disturbance can be detected in the area. This is testified by the negative value found in winter (-0.008).

TABLE 6 - One-way ANOSIM results of the assemblages abundance structure between sampling stations (R values and significance level, P). Global R=0.892. SIMPER result showing the average dissimilarities (%), the most contributing to the dissimilarity, and its contribution ratios to the average dissimilarities between stations.

Groups	One-way ANOSIM		SIMPER		
	R value	P value	Average Dissimilarity (%)	Discriminating species	Contribution (%)
group 1 vs KL	0.854	0.036*	91.85	*Pagurus forbesii*	9.66
group 1 vs group 2	1	0.143	78.59	*Athanas nitescens*	9.68
group 1 vs group 3	0.885	0.036*	79.35	*Xantho pilipes*	7.72
KL vs group 2	1	0.33	76.60	*Pagurus forbesii*	33.24
KL vs group 3	1	0.33	79.41	*Pagurus forbesii*	20.25
group 2 vs group 3	1	0.33	76.27	*Processa nouvelli nouvelli*	15.72

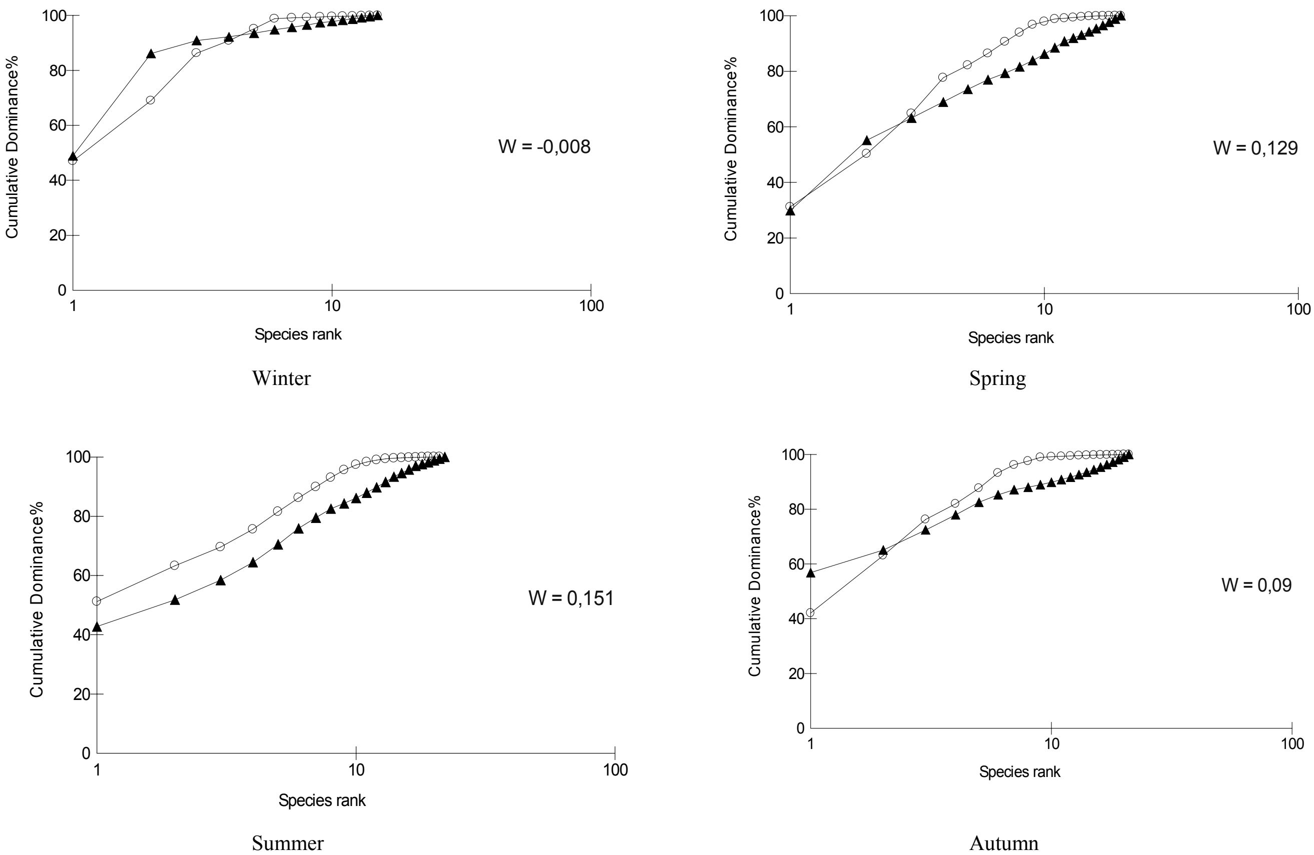


FIGURE 5 - Abundance-Biomass Comparison (ABC) plots for the Deacapod fauna of Canakkale Strait (○: Abundance, ▲: Biomass).

4. DISCUSSION AND CONCLUSIONS

Considering the totality of collected specimens, even though distribution presented gaps in stations and/or seasons, we can conclude that Canakkale Strait hosts a quite diverse decapod fauna (45 species), represented almost completely by rare species, with the exception of few ones. Boero [29] reported that rare species can play a significant role in the description of the communities. These species can in fact represent an important source of diversity within the assemblages itself, thus allowing a certain number of adjustments in the assemblages composition in response to biotic and/or abiotic disturbance.

The total abundance was not very high, showing its maximum in winter and minimum in spring (847 decapod specimens m^{-2} in winter, 295 in spring, 641 in summer and 358 in autumn), while biomass did not follow the same pattern (maximum in winter followed by a gradual decrease through the other seasons (Table 4). Comparing total abundance and biomass, decapods seem to be represented by a high abundance of large specimens in winter, followed by an abrupt decrease of abundance and an increase in size during spring. Summer seems to host a large population of very small individuals, which grow up during autumn. Thus, it seems that spring could be considered as decapods reproductive period in Canakkale Strait. On the other hand, the decrease of total abundance from summer to autumn could be caused by both the regression of algae, acting as hosts, and pressure of predators.

Considering the most abundant species, both in abundance and biomass (Table 4) we can see that *A. nitescens* clearly follows the same pattern, as it presents the bigger specimens in spring and a large number of individuals of low biomass in summer and autumn. On the contrary, data on *X. pilipes* and *P. spinifer* suggest that their reproductive period could be placed in winter, but the observed abundance in this study is too low to hazard any conclusion.

Zupo [30] and Lopez de la Rosa et al. [24] reported a similar decrease of decapod abundance in spring, in areas with two recruitment periods. Garcia Raso [31] reported *Athanas nitescens* as dominant from April to October in *Posidonia oceanica* beds, while in the present study the species had its highest abundance in winter. The reasons of this difference could be linked to different habitat type and hydrographic conditions. Indeed, seasonal grain size analyses in the studied area showed significant fluctuation at each station, with coarser sediments during winter and spring, due to sediment instability caused by winter winds, and finest sediments in summer and autumn, as a result of lower wind and lower currents [22]. In this case, it is obvious that individual settlement was favoured in periods and areas with milder conditions, getting higher diversity in finer sediments (summer, autumn) and higher abundance in coarser sediment (winter). This is in some way opposite to the generally observed situation in other areas, where sites with finest sediment do not show changes in winter, but present substantial seasonal faunal changes in the coarser sediments [32].

Considering the total 45 decapod species identified in the study area, it is worth noticing that 44 species were encountered from shallow waters (sampling depth between 7 and 26 m), while only six of them and *Goneplax rhomboides* were obtained from depths between 30 and 80 m. In soft bottoms, the increase of the finest fractions in the sediment [33] results in the decrease of habitat heterogeneity [31, 34], thus in the decrease of microhabitats favouring a greater biodiversity [35, 36]. As a consequence, a negative correlation between biotic factors and clay-fraction and a positive correlation between biotic and fine sand bottoms are to be expected. It is also known that both number of species and individuals abundances are higher in fine sand bottoms [31, 36-38]. However, in this study it has been found that number of species, abundance, biodiversity and richness tended to be lower in fine sand and higher in finest or coarser sediments. The same results were obtained in studying peracarid assemblages in the same area [22]. Reduced diversity of benthic assemblages in sandy substrata has been reported in stressed conditions [39]. ABC analysis showed that Canakkale Strait is subjected to a natural stress. Hydrodynamic conditions could be appointed as the main stress factor, as currents have been indicated as the most important factor of environmental control, modifying the granulometric composition and amount of organic matter in the sediment [24, 32, 35, 40].

Aydın & Sunlu [41] reported that TOC value is lower in the south Aegean than in Canakkale Strait, probably reflecting differences between the strongly eutrophic Black Sea and the oligotrophic/mesotrophic Aegean Sea. Dense maritime traffic, strong current regime and storms, human activities like aquaculture may have caused the increase of TOC value in the study area. It is indicative that the highest TOC value was measured at station KY, where some aquaculture activities were operating in the past. Organic matter enriching surface sediments constitutes a significant food source for zoobenthos [42] According to the same author' classification, TOC values are separated in three groups: high (>35 mg g^{-1}), low (<10 mg g^{-1}), and intermediate (between 10 and 35 mg g^{-1}) concentrations. Thus, values from Canakkale Strait (between 0.54 and 22 mg g^{-1} [22]) can be accepted as low and intermediate, probably positively acting on decapod assemblages by enhancing the trophic web of the area. This is testified by the positive correlation of TOC with species number, biodiversity and richness of decapods.

It is known that velocities of the bottom and surface water masses of Canakkale Strait change seasonally from 20 to 40 cm s^{-1} and from 50 to 200 cm s^{-1}, respectively [18] while TOC and TN concentrations in sediments increased in summer and autumn. Biernbaum [32] suggested that the great faunal change observed in winter involves sediment instability caused by winter winds. Areas having high negative skewness together with high gravel content in winter indicate a significant bottom scour. The strong winter currents of the study area increase the sifting of the sediments thus reducing turbidity. Indeed, the lowest turbidity was measured at winter and increased thereafter reaching its peak in summer [22]. Mucha and Costa [14] showed that hydrodynamism appears to be a stabilizing factor for macrobenthic assemblages. Strong hydrodynamism, decreasing organic load and fine fraction sediment content, foster less reducing conditions, and concomitantly result in a decrease in nutrients reduced forms and an increase in nitrate contents in interstitial water. These conditions lead to a reduction in the disturbance state of the assemblages. Although sediment properties change seasonally in the Canakkale Strait, the high hydrodynamism and its two different current systems may justify some peculiarities of this area. Garcia-Raso & Manjon-Cabeza [43] reported that decapod assemblage living in a strongly hydrodynamic area is well adapted to this condition and better resists disturbances. According to all applied analyses (PERMANOVA and ANOSIM), no seasonal difference in decapod assemblages from Canakkale Strait was detected. The lack of seasonal differences could be due to the complexity of biotopes, the interaction between assemblages and species moving between substrates [44].

Also García-Raso & Muñoz [45] reported that decapod assemblage is stable due to some properties like strong hydrodynamism. Moreover, Mucha & Costa [14] suggested that enrichment can be observed not only in terms of phyla and species but also in terms of trophic and dynamic groups, involving a wide range of ecological behaviours. Decapod species from Canakkale Strait revealed a very diverse trophic status: carnivore, deposit feeder, suspension feeder, omnivor. Most of the species can adopt different feeding types, leading to a big advantage in order to survive in such a hard environment. Discriminating species were significantly correlated with different sediment variables and there might be a niche partitioning in order to avoid direct trophic competition for resources linked to the sediment variables [46]. *Pisidia blutelii* and *Athanas nitescens* showed a positive correlation with the percentage of medium gravel and *Athanas nitescens* showed also a negative correlation with the percentage of sand in sediments. Abele [47] suggested that composition of decapod species and dominance are determined by substratum. Likewise, feeding behavior and biogenic detritus where they live, allow them to survive among the shell remains and gravel, protected from strong bottom currents. Other factors such as the presence, or the increase, of seaweed could affect the structure of decapod assemblages. The type of substratum (sediment and seaweed) and its evolution determine the dominance and composition of decapod species living in detritic bottoms [48].

A particular situation was observed at station KL, where decapods were absent during cold seasons, but a few scavenger species were present during warm seasons, together with the invasive alien species *Caulerpa racemosa,* considered their preferred source of detritus [49]. Decapod assemblages in *Caulerpa racemosa* are very diverse and highly abundant [50] due to an increase in habitat complexity. *Pagurus forbesii*, here firstly recorded from the Turkish Strait System (TSS) and *Paguristes syrtensis* are characteristic of detritic bottoms [44]. Vazquez-Luis et al. [51] reported that the effects of *C. racemosa* on habitat structure were more important during warm season, due to its life cycle. This invasive species could be responsible for the increased biodiversity of the “barren” station KL and consequently directly affecting TSS. Thus, it seems that the presence of these scavengers in this station only during warmer seasons is closely related to the presence of *Caulerpa racemosa* in the area.

To summarise, the study of composition and distribution of decapod fauna in the different seasonal sediment composition of Canakkale Strait revealed that they are directly influenced by the high hydrodynamism and the two different current systems of the area. Further investigation should be devoted to monitoring of species and their relationships, in order to predict impact of natural or human induced stress conditions.

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