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Recent data on the effects of sewage pollution on the assemblage of decapod crustaceans in the Dardanelles (the Turkish Straits System)

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Abstract: The present work was performed to have the knowledge regarding the effects of sewage pollution on the decapod crustaceans assemblage collected at depths of 0-5 m of the Dardanelles. The samples presented herein were collected on the soft-bottoms by a SCUBA diver between July 2008 and April 2009. A total of 460 specimens belong to 25 decapod species was found and among these, the hermit crab, *Diogenes pugilator* has the highest dominance value of Di%=74.35). Multiregression approach resulted in statistically insignificant relationship between physical, chemical and biochemical parameters of water and sediment and decapod species.

Keywords: Sewage pollution, decapod community, crustacea, the Dardanelles, Turkey.

Introduction

Sewage pollution that have been observed in all aquatic ecosystems, affecting water resources if not properly treated before discharge (Botkin and Keller 2003). The pollution in the coastal water is one of the most significant problems with regard to the activities such as fishing, swimming and the protecting of biodiversity. Recently, for Turkey, wastewater treatment is a major problem due to around 45% of domestic wastewater is dumped into sea environment (TSI 2006). The Black Sea is connected by the Turkish Straits System including the Bosporus and the Dardanelles. The Dardanelles is an important gateway that connects the Aegean Sea and the Sea of Marmara. At the same time, urbanizations in the coastal areas and inputs belonging to the ships passes the Dardanelles are major reasons for the pollution. As known, 50000 ships passes through the Dardanelles every year, approximately. The shallow waters of the Dardanelles, however, are more polluted by two vectors indicated above. The effect of wastewater disposal on coastal zone is generally known as eutrophication.

The eutrophication is observed especially during August period. Yet, dilution of water pollution with respect to higher precipitation and therefore runoff do not cause eutrophication in the winter period. Due to sewage pollution has an important effect on benthos, crustaceans are mostly known as bioindicators in various aquatic ecosystems, especially for polluted waters (Rinderhagen *et al*. 2000). The structure of benthic community is determined by change quantity in pollution (Arasaki *et al*. 2004). These temporary changes are mostly observed in organic matter and sensitive species such as crustaceans soon leave the polluted area (Bat *et al*. 2001). Maps of pollution gradients can be composed by defying the community structure and distribution of indicators in marine environments (Corbera and Cardell 1995). Many works regarding this topic have been performed on polychaetes and molluscs, especially (Bellan 1967).

Crustaceans are the most sensitive group among benthic assemblages affected by sewage pollution (Del Valls *et al*. 1998, Bat *et al*. 2001, Guerra-García and García-Gómez 2004). Many studies were carried out as regards the effects of sewage pollution on crustaceans found in various localities of the Mediterranean. Del Valls *et al*. (1998) and Guerra-García and García-Gómez (2004) carried out the studies on the effects of sewage pollution on crustaceans of soft bottoms, respectively. With regard to the subject, Garcia Raso and Manjon Cabeza (2002) detected the effects of pollutants resulting from domestic pollution on decapod crustaceans found in the upper-infralittoral zone of Barbate Coast (the southern Spain). Corbera and Cardell (1995) studied the distribution of cumaceans affected by eutrophication in the soft bottoms of Barcelona coast in the southern Spain.

As for the Turkish coast, Bat *et al*. (2001) determined the effects of domestic wastewaters on several crustacean species in shallow waters of the coast of Sinop Harbour (the southern Black Sea). Then, Tuğrul İçemer and Koşun (2003) carried out a study for underlining on the benthic community structure of sewage pollution observed in Antalya Bay (Eastern Mediterranean).

The impacts of pollution on benthic assemblages observed on the Turkish coast were stated in previous studies (e.g., Kocataş *et al*. 1988, Bat *et al*. 2001, Tuğrul İçemer and Koşun 2003, Albayrak *et al*. 2006, Yüksek *et al*. 2006). But, there is no detailed study about the effects sewage pollutants on the macrozoobenthic communities of the Dardanelles. The goal of the present study is to determine the effects of sewage pollution on the assemblages of decapod crustacean found on soft bottoms of the Dardanelles.

Material and Methods

Sampling sites

Study area is composed of 8 sampling sites and their GPS coordinates are shown. 1. Gelibolu; 40°40´617˝N 26°66´692˝E, 2. Lapseki;

40°34′661″N 26°67′985″E, 3. Çanakkale; 40°15′474″ N 26°40′879″ E, 4. Kilya Inlet (reference site); 40°20′472″N 26°36′117″E, 5. Eceabat; 40°18′253″N 26°36′046″E, 6. Kilitbahir; 40°15′048″N 26°37′878″E, 7. Kepez Harbour (reference site); 40°10′360″N 26°37′339″E, 8. Dardanos; 40°07′493″N 26°35′806″E (Fig. 1). Specimens of decapod at the depths between 0 and 5 m were sampled as three different transects (depth counters of 0.5, 2 and 4 m) by means of a quadrate system of 30x30 cm by a Scuba diver and preserved in buffered formalin. Seasonal samplings were performed in July, November 2008 and February, April 2009.

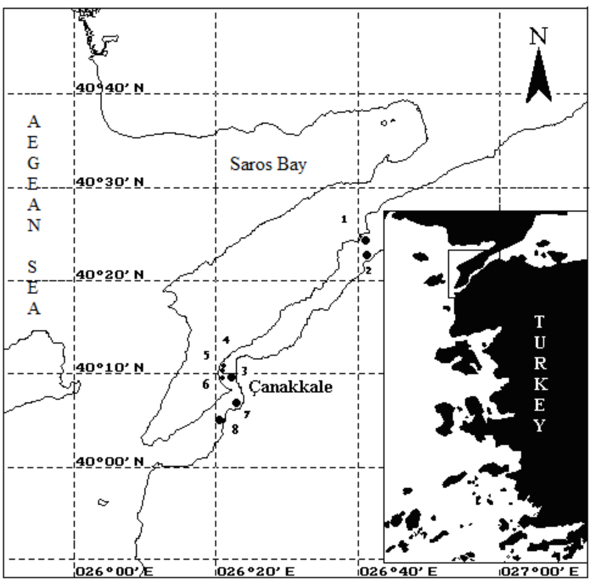

Figure 1. The map showing the sampling site in the Dardanelles (1: Gelibolu, 2: Lapseki, 3: Çanakkale, 4: Kilya Inlet, 5: Eceabat, 6: Kilitbahir 7: Kepez Harbour, 8: Dardanos).

Bottom structure of sampling points

The depths of sampling were chosen in localities that pouring down domestic waste to the marine environment. Also, the depth of each sample had a different bottom structure. The community structure of decapod crustaceans and the amount of pollutants is related with respect to this article's concept. While the part between 2 and 5 m at Kilitbahir sampling point is partly covered by the Mediterranean mussel, *Mytilus galloprovincialis,* Kilya reference station had a bottom of silty. The bottom at the depths of 2-4 m of Eceabat station is covered with meadows, *Zostera marina.* While Lapseki site has fine sand, Çanakkale point is partly covered by photophilic algae and coarse sand with rocks. The bottom at depth of 4 m of Kepez Harbour is dominated by mytilid bivalve, *Mytilus galloprovincialis*. Dardanos sampling site is covered with meadows, *Zostera marina.* Content of organic matter in sediment was determined by 550 °C incineration of washed known weight of sediment samples (generally 50 grams) for two hours. In this process the high temperature oxidation method presented by Craft *et al*. (1991) was used.

Sea Water Quality Parameters

Environmental variables such as dissolved oxygen, water temperature, electrical conductivity, pH, and salinity were measured by means of YSI 556 model MPS in field. Seawater samples were taken by using dark color clean glass bottles of 1 liter. The amounts of NH_4, NO_3, NO_2, BOD, COD, and anionic detergents were measured using Standard Methods (APHA, AWWA and WEF 2005). Moreover, water organic constituents were determined using Hach-5000 spectrophotometer. Tests for all variables replicates were applied as three replicates and statistically no difference were found after data evaluation. Quality control was ensured when testing parameters in laboratory.

Ecological Data Analyses

To diagnose the samples belonging to decapods found from the study area, a triocular stereo microscope was used. Specimens of decapod crustaceans were diagnosed on the basis of studies of Zariquiey Alvarez (1968), Noël (1992), Falciai et Minervini (1996). In order to determine the community structure, Soyer's (1970) frequency index

(¦f%), Bellan-Santini's (1969) quantitative dominance index (Di%), Shannon's diversity index (H′) as well as its evenness component (J′) and Bray-Curtis's (1957) similarity index were calculated. For the same purpose, group-averaging cluster analysis based on the Bray-Curtis similarity was used. In calculating of Shannon's diversity index (H′) as well as its evenness component (J′) primer program 6.0 was used.

The frequency index of a particular species was estimated by

$f = (m/M) x 100$

where,

m is number of stations where species of concern exists

M is number of all stations

The dominance index of a certain species was estimated by Di = (m/M) x 100, where m = individual number of a species in the stations and M = total individual numbers of all species.

The Shannon-Weaver diversity index was estimated by

$H' = - \Sigma p_i x (\log_2 p_i)$,

where S = total individual number of a species and N =total individual numbers of all species.

The Pielou evenness index was estimated by

$J' = H' / \log_2 S$

where H'= Shannon index value; S = species number

Bray-Curtis $Sjk=100 \{1- |\Sigma|y_{ij} - y_{ik}|/\Sigma|yij + yik||\}$

Statistical Data Analyses

The statistical differences between sampling sites and sampling time (seasons) were detected by using variance analyses. These analyses were completed using SPSS 10.0. Besides, the physical and chemical variables of seawater were tested to determine which ones are correlated. Friedmann test was applied to know the distribution of decapod crustaceans depending on the seasonal changes.

$F_D = [12 / (b \times t \times (t+1)] \times \Sigma[(S_j)^2 - (3 \times b \times (t+1)]$

where, b is number of sampling stations (8) and t is number of seasons (4)

S_j : standart deviation of the data set

All variables collected were evaluated using MANOVA (multiple analysis of variance). Spearman correlation (r_s) was used to evaluate the correlations between species composition and polluants.

Results

Environmental variables

The mean values of concentration of dissolved oxygen (DO) was noted to be 7.13 (±0.59) mg/L. Çanakkale site had the highest DO concentration of 9.79 mg/L in April 2009. Otherwise, Lapseki discharge point was found to have the lowest DO value (3.68 mg/L) in July 2008. Average value of salinity was seasonally computed to be 25.52 (±1.30) ‰ for all sampling sites and periods. While Dardanos discharge sampling point had the highest salinity value (30.5‰) in November 2008, the salinity value for Lapseki discharge site was measured as 23.6‰ in April 2009. Mean sea water temperature among all sites and sampling times was determined to be 16.02 (±5.82) °C for sampling area. The highest sea water temperature (26.77 °C) was recorded at Kilya reference point in July 2008, despite the fact the lowest (8.87 °C) was recorded at Gelibolu discharge site in February 2009.

Table 1 shows all the values of physical and chemical variables recorded in the sampling area. The differences in the values of DO, pH and sea water temperature for only sampling periods are statistically remarkable. Yet, both sampling periods and sampling sites were found to create statistical differences in salinity and electrical conductivity according to two-way analysis of variance (MANOVA)

Table 1. The values of dissolved oxygen, seawater temperature, seawater salinity, pH, electrical conductivity measured in the study area.

Sampling Period	July 2008					November 2008					February 2009					April 2009				
	Parameters																			
Stations	O_2 mgL	T (°C)	S (‰)	pH	EC mS/cm	O_2 mgL	T (°C)	S (‰)	pH	EC mS/cm	O_2 mgL	T (°C	S (‰)	pH	EC mS/cm	O_2 mgL	T (°C)	S(‰)	pH	EC mS/cm
Çanakkale (D)	4.19	23.7	23.3	8.21	53.78	5.00	15.25	25.6	8.32	32.69	9.63	9.18	27.8	5.30	30.40	9.79	14.26	24.4	7.07	30.50
Lapseki (D)	3.68	24.57	22.6	8.15	51.56	3.34	15.70	24.6	8.25	31.83	9.65	9.31	27.4	6.40	30.05	8.72	13.68	23.6	6.85	29.61
Gelibolu (D)	5.58	25.03	22.8	8.33	53.08	5.56	16.17	25.5	8.51	33.17	9.61	8.87	27.6	7.48	33.17	8.13	13.10	24.3	6.50	29.60
Kilya Inlet (R)	8.46	26.77	23.1	8.53	53.57	5.90	16.30	25.7	8.55	33.61	9.25	9.24	26.5	7.55	29.07	7.95	13.50	23.3	6.48	28.84
Eceabat (D)	7.40	25.60	22.9	8.39	53.19	6.01	16.01	25.5	8.46	33.13	9.56	9.24	27.4	8.09	29.98	8.90	13.31	24.2	6.52	29.62
Kilitbahir (D)	5.16	25.1	23.1	8.31	53.37	5.68	16.37	25.6	8.33	33.50	9.20	9.12	27.6	8.79	30.10	8.90	13.23	24.3	7.05	29.70
Kepez Harbour (R)	5.14	24.39	23.5	8.30	54.93	5.28	16.22	26.1	8.45	33.96	5.68	9.65	28.3	5.44	31.21	8.65	14.10	24.8	6.74	30.97
Dardanos (D)	6.49	24.36	28.1	8.44	64.32	5.83	16.07	30.5	8.70	38.93	7.94	9.61	28.3	5.13	35.31	8.04	15.75	28.6	6.88	36.32

DO (mg/L): Dissolved oxygen. T (°C): Seawater temperature. T (‰): Seawater salinity. pH: Activity of Hidrojen ion. EC (ms/cm): Conductivity

Sewage Pollutants

The concentration of NH_4 for all sampling periods and sites was computed as 35.94 (±50.26) mg/L on average. The highest ammonia levels belong to Çanakkale and Lapseki discharges as 168 and 166 mg/L in July 2008, respectively. Kilya and Kepez harbour points have the considerable low NH_4 values of 0.06 mg/L (both) in April 2009. Furthermore, Kilya reference site was found to be the cleanest on account of NH_4 content, the values belong to this site are 0.05 mg/L for February 2009 and 3.68 mg/L July 2008, respectively.

The highest level (0.85 mg/L) of NO_3 was measured at the Lapseki point in November 2008. This value for Çanakkale and Eceabat discharges sites was the lowest (0.01 mg/L) in February 2009. Based on the sampling period, average concentration of NO_3 was the lowest (0.14 mg/L) at Eceabat discharge. At the same time, the highest nitrate level of 0.54 mg/L was recorded at the Lapseki discharge site. Mean level of NO_2 for the sampling periods and locations was 0.057 (±0.04) mg/L. The maximum level of NO_2 was recorded for the Gelibolu site as 0.158 mg/L in February 2009. Otherwise, Dardanos discharge point had the lowest concentration of NO_2 (0.004 mg/L) in summer period. Consedering the sampling period, level of mean NO_2 was the lowest (0.034 mg/L) at Kilitbahir discharge site. Average PO_4 concentration of all sampling times and locations was computed as 0.85 (±1.14) mg/L. The maximum PO_4 level was found at the Gelibolu discharge as 4.78 mg/L in July 2008. Contrary, lowest PO_4 level was measured at Kilya reference site as 0.05 mg/L in February 2009. Considering sampling period mean phosphate, the lowest (0.38 mg/L) was detected at Kepez harbour site among all individual samplings (Table 2).

Table 2. Ammonia, nitrate, nitrite, and phosphate concentrations (mg/L) found during the study.

Sampling Period	July 2008				November 2008				February 2009				April 2009			
Stations	NH_4	NO_3	NO_2	PO_4	NH_4	NO_3	NO_2	PO_4	NH_4	NO_3	NO_2	PO_4	NH_4	NO_3	NO_2	PO_4
Çanakkale (D)	168	0.08	0.012	1.34	56.1	0.76	0.079	0.09	48.3	0.01	0.105	0.06	0.72	0.16	0.018	0.10
Lapseki (D)	166	0.4	0.031	3.27	121	0.85	0.092	1.14	7.8	0.74	0.057	1.18	0.13	0.15	0.014	0.15
Gelibolu (D)	1.47	0.32	0.113	4.78	1.89	0.60	0.041	0.34	1.62	0.15	0.158	0.56	0.41	0.22	0.036	0.14
Kilya Inlet (R)	72.4	0.28	0.039	1.55	11.6	0.34	0.028	0.08	0.05	0.42	0.074	0.05	0.06	0.18	0.034	0.13
Eceabat (D)	33	0.11	0.036	2.69	52	0.12	0.047	0.26	77.1	0.01	0.092	1.19	3.90	0.31	0.047	0.10
Kilitbahir (D)	33.7	0.02	0.031	1.32	13.5	0.15	0.038	0.38	3.5	0.17	0.023	2.91	1.93	0.41	0.043	0.35
Kepez Harbour (R)	14	0.28	0.074	1.13	12.9	0.11	0.096	0.12	16	0.20	0.151	0.09	0.06	0.60	0.036	0.17
Dardanos (D)	131	0.32	0.004	1.26	97.3	0.41	0.034	0.09	2.71	0.40	0.118	0.13	0.40	0.20	0.037	0.09
Average and Standart Deviation	77.4 (68.3)	0.23 (0.14)	0.043 (0.035)	2.17 (1.31)	45.8 (44.2)	0.42 (0.29)	0.057 (0.028)	0.312 (0.355)	19.64 (23.61)	0.26 (0.25)	0.10 (0.05)	0.77 (0.99)	0.91 (1.33)	0.28 (0.16)	0.033 (0.011)	0.15 (0.08)

Average organic matter (percent SOM) in the sediment for all sampling times and sites was 2.85 (±2.16) %. The maximum level of SOM (9.86%) was recorded at Lapseki discharge in spring of 2009 possibly due to less variation in temperature, continuous sewage discharge and structure of the site since it is less affected by flow in the strait. The lowest SOM (0.55%) was measured at Kilitbahir discharge because of the fact that the highest flow in the strait is near this site. Predictably, Kilitbahir point had the lowest SOM (1.75 %). Mean anionic detergent of all sampling times and locations was computed as 0.04 (±0.02) mg/L. The highest detergent value (0.105 mg/L) was recorded at Gelibolu discharge site in summer of 2008. The lowest value was 0.011 mg/L at Kepez harbour probably due to the fact that there is a wastewater treatment plant and the only one in the study area treating domestic pollutants serving houses within Kepez municipality and surface strong current coming from the Sea of Marmara in this point. Considering the amount of anionic detergent, Kepez and Kilya reference points was the cleanest with a value of 0.19 mg/L. Mean anionic detergent level was computed to be 0.63 and 0.62 mg/L at Gelibolu and Lapseki discharge points to be the highest among all sampling stations taking into account only of the sampling sites (Table 3).

Table 3. Sediment organic matter and anionic detergent measured during the study

Sampling Period	July 2008		November 2008		February 2009		April 2009	
	Parameters							
Stations	‰ OM	AD (mg/L)	‰ OM	AD (mg/L)	‰ OM	AD (mg/L)	‰ OM	AD (mg/L)
Çanakkale (D)	8.22	0.058	16.7	0.078	22.5	0.056	50.2	0.048
Lapseki (D)	14.1	0.067	13.7	0.053	22.5	0.083	98.6	0.045
Gelibolu (D)	8.75	0.105	34.9	0.057	13.1	0.049	45.0	0.039
Kilya Inlet (R)	11.4	0.028	12.9	0.021	15.1	0.014	56.9	0.014
Eceabat (D)	12.3	0.066	28.5	0.037	11.0	0.061	44.3	0.041
Kilitbahir (D)	5.50	0.019	18.9	0.029	18.8	0.044	26.6	0.033
Kepez Harbour (R)	16.2	0.024	19.4	0.027	20.1	0.013	46.3	0.011
Dardanos (D)	72.9	0.027	28.6	0.026	33.2	0.018	65.8	0.014
Average and Standart Deviation	18.7 (22.2)	0.05 (0.03)	21.7 (7.99)	0.041 (0.02)	19.5 (6.96)	0.04 (0.03)	54.2 (21.2)	0.031 (0.015)

OM: sediment organic matter (‰) and AD: Anionic Detergent (mg/L)

Faunal Data

A total of 460 individuals belong to 25 decapod species found in the soft-bottoms of the depths between 0 and 5 m of 8 different sampling points (6 discharges, 2 references) in the Dardanelles was reported. The hermit crab, *Diogenes pugilator* has the highest dominance value of 74.35% (n=342 ind.). The species that have the second the highest value was the caridean shrimp, *Athanas nitescens* with value of 9.13% (n=42 ind.). The lowest value (Di%=0.21, n=1 ind.) is belong to the caridean shrimps, *Hippolyte inermis*, *Philocheras fasciatus*, *Processa* sp., the hermit crab, *Pagurus prideaux*, the crabs, *Liocarcinus navigator*, *Parthenope massena*, and *Xantho pilipes*. The annual values of dominance of the decapod crustaceans found is shown in Table IV. 52% of decapod species reported here appeared to constitute permanent components of the fauna (with f% values >50). During spring period, there was a highest number of individuals (n=130 ind.) of the hermit crab, *D. pugilator*, while the caridean shrimps, *A. nitescens*, *Crangon crangon*, *P. fasciatus*, the crabs, *Carcinus aestuarii*, and *P. massena* were observed in this period with a maximum number of individuals (n=1).

Table 4. The dominance (Di%) values of *Diogenes pugilator* on the basis of the sampling depths.

	Depths (m)		
Station	**0.5**	**2**	**4**
Kilitbahir	7.60	13.45	14.03
Eceabat	0	5.84	6.14
Kilya Inlet	15.20	7.30	8.77
Gallipoli	2.63	4.09	2.04
Lapseki	0	0.29	1.16
Çanakkale	0.29	3.8	0
Kepez Harbour	0.58	2.33	0.58
Dardanos	1.46	2.33	0.58

Table 5. The values of total specimen number (Σ), dominance (Di%), and seasonal occurrence frequency (f%) of decapod crustaceans found in the study area.

Species	Σ	Di%	f%
Decapoda			
Alpheus macrocheles	6	0,10	50
Athanas nitescens	42	0,73	100
Crangon crangon	7	0,12	50
Eualus cranchii	6	0,10	100
Hippolyte inermis	1	0,02	25
Philocheras bispinosus	2	0,03	25
Philocheras fasciatus	1	0,02	25
Processa macrophthalma	2	0,03	50
Processa sp.	1	0,02	25
Anapagurus petiti	2	0,03	25
Diogenes pugilator	342	5,98	100
Pagurus cuanensis	6	0,10	25
Pagurus prideaux	1	0,02	25
Pisidia longimana	14	0,24	100
Upogebia pusilla	2	0,03	50
Carcinus aestuarii	6	0,10	75
Liocarcinus navigator	1	0,02	25
Liocarcinus depurator	2	0,03	50
Liocarcinus maculatus	6	0,10	25
Liocarcinus marmoreus	2	0,03	25
Liocarcinus sp.	2	0,03	25
Parthenope massena	1	0,02	25
Pilumnus hirtellus	2	0,03	50
Sirpus zariquieyi	2	0,03	50
Xantho pilipes	1	0,02	25

Kilitbahir site had the highest number of individuals (n=132), and the lowest value (n=6) was found at Lapseki discharge site (Figure 2). Considering the number of the species according to the sampling stations, the maximum species was observed at Dardanos point with 13 species. Kilya reference point had the least species (n=1). Considering the species number recorded throughout the year, while the maximum species (14) was recorded in spring of 2009 at least species (10) was found in autumn 2008 and winter 2009. Besides, the maximum number of individual (n=152) was recorded in spring of 2009. The lowest value (n=71 ind.) was found in summer 2008 (Figure 3).

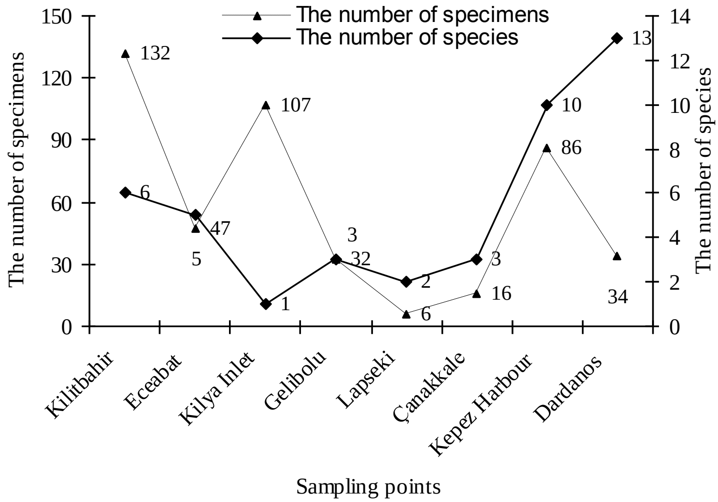

Figure 2. The number of species and specimens found at the sampling points.

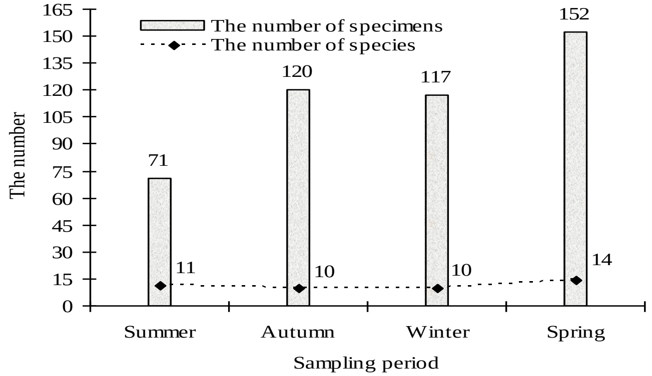

Figure 3. The number of species and individual recorded during the sampling seasons.

The difference between the diversity index values (H′) belong to the sampling stations was not more and H′ values were quite low (between 0.23 and 0.29). The evenness index (J′) values belong to the stations mainly ranged between 0.76 and 0.98 (Figure 4). H′ value (0.23) for Kilya station was lowest because only single species was recorded.

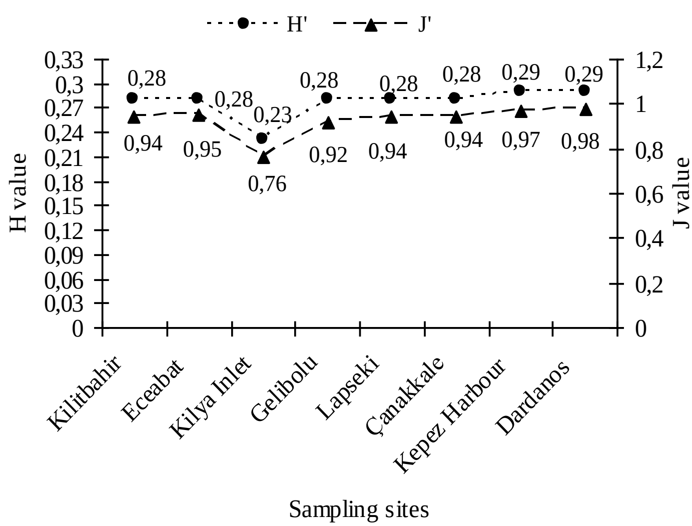

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Figure 4. Values of the diversity (H′), evenness (J′) at the sampling sites

The seasonally values of the diversity indices were very similar and the diversity (H′) was highest (H′=1.09) in April 2009. The diversity index values (H′) in sampling seasons ranged between 0.94 and 1.09. Also, the evenness index (J′) values belong to the sampling periods mainly ranged between 0.94 and 0.95 (Figure 5).

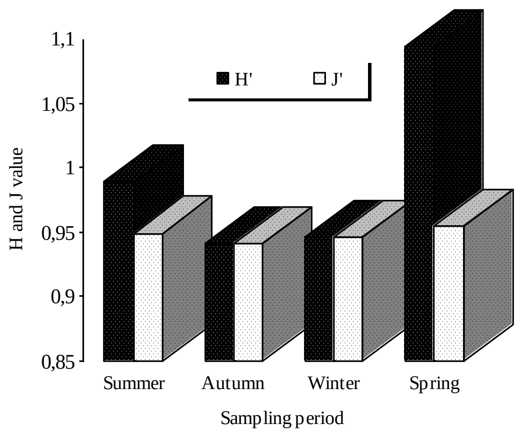

Figure 5. Values of the diversity (H′), evenness (J′) in the sampling periods.

According to these results the decapod crustaceans found in the study area were generally more abundant in the spring as compared to other seasons. The results of the Bray-Curtis similarity index show that spring 2009 and autumn 2008 shared the same similarity groups with a value of 64.81%. Besides, the similarity value was 56.47% between autumn 2008-spring 2009 group and summer 2008 (Figure 6). The sites that the most similar to each other in terms of similarity index were Kilya and Kilitbahir sites (similarity index value: 89.49%). Bray-Curtis similarity analysis indicates that Gallipoli and Eceabat points composed a second similarity group with a value of 76%. The similarity between Lapseki discharge point and the other sampling sites was 36.17% (Figure 7).

Calculation of Spearman's rank correlation coefficient (r_s) between biotic (abundance at the sites) data and domestic pollutants (NH_4, NO_3, NO_2, PO_4, and anionic detergent) parameters revealed a statistically non-significant correlation ($p<0.05$). A positive correlation ($r_s = 0.43$; $p < 0.05$) is observed between the abundance (ind.m^{-2}.) and the content of organic matter at the stations. Moreover, a more significant correlation ($r_s = 0.63$; $p < 0.05$) was observed between the number of species and the level of organic matter at the sampling points.

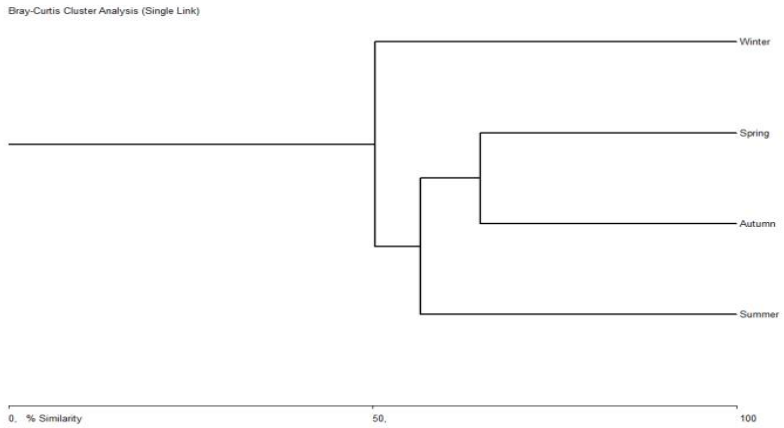

Figure 6. Similarity of the cumacean community in the sampling seasons (Bray Curtis index).

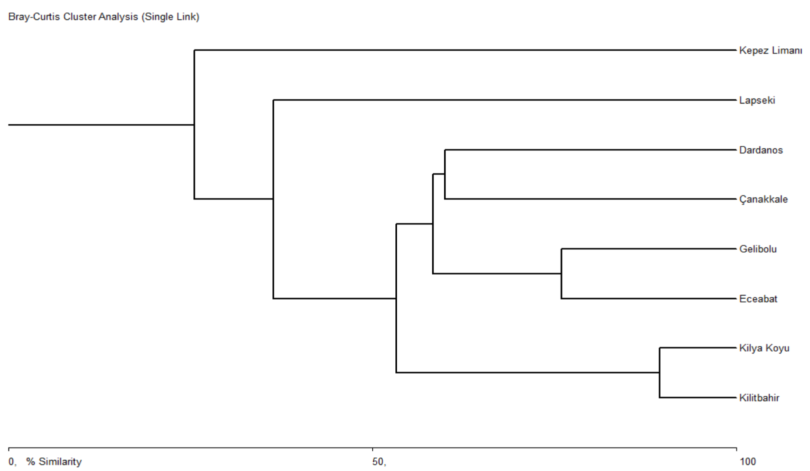

Figure 7. Similarity of the cumacean community at the sampling stations (Bray-Curtis index).

In addition, Bentix pollution index was used in this study. According to this index, $2 \leq B \leq 2.5$ poor, $2.5 \leq B \leq 3.5$ moderate, $3.5<B<4.5$ good, and $4.5<B<6$ are valid for high ecological status (Simboura and Zenetos, 2002). In this study, as the bentix values of the sampling sites ranged from 2.0 to 5.3, these values for the sampling periods were between 2.5 and 3.4 (Fig. 8, 9). Considering the bentix values belong to the sampling seasons, moderate pollution can be mentioned for the all sampling area. On the contrary, in the values of all sampling points an excessive pollution of 62% was reported for the coastal system of the Dardanelles.

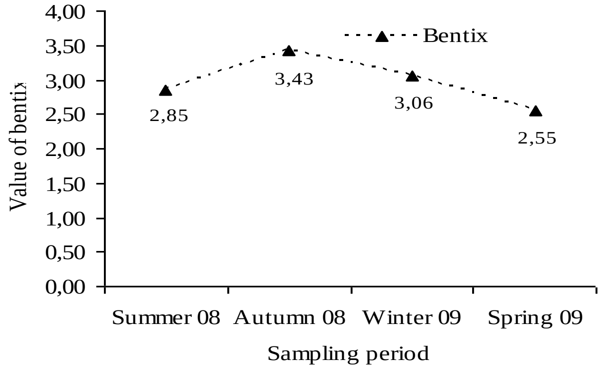

Figure 8. The bentix values belong to the sampling periods.

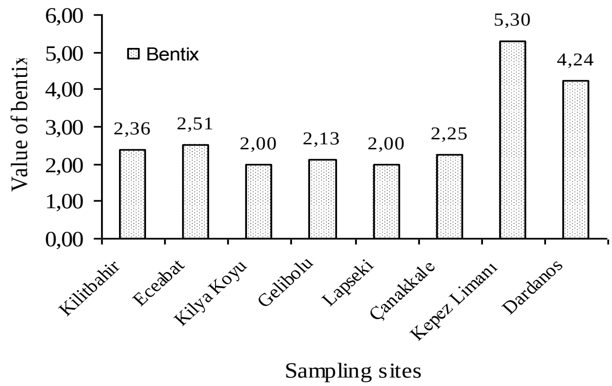

Figure 9. The bentix values belong to the sampling stations.

According to the reults of analysis of multiple linear regression between the decapod species found the physical, chemical, and bio-chemical variables belong to seawater and sediment, excluding *Pagurus cuanensis*, *Pagurus prideaux*, *Pisidia longimana*, and *Liocarcinus maculatus*, the other species were not statistically significant dependence on the parameters measured as a result of this study. The hermit crab, *Pagurus cuanensis* is associated with multiple regression analysis R2 = 0.845 (= 84.5%), F = 3.638 (p = 0.013) in 95% confidence interval selected EC (electrical conductivity of water) (β = 0.135, t = 2.322 (p = 0.039)) ; BOD5 (β = 2.464, t = 2.945 (p = 0.012)) and COD (β = -1.577, t = -2.913 (p = 0.013)) level. So, while the species is biochemically tolerant for biodegradable pollutants, it has a less tolerant for biodegradable chemical pollutants. When the water electrical conductivity rises, the number of individuals of this species increases.

As the result of multiple regresion analysis, other hermit crab, *Pagurus prideaux* is a remarkable species depending on PO_4 at level of R^2 = 0,809 (=%80,9); F= 2,822 (p=0,036). For PO_4 β= 0,150; t= 3,204 (p= 0,008) the statistical values were obtained and the number of individual belong to the species increased depending on the concentration of phosphate in the seawater.

According to the results of analysis, the hermit crab, *Pisidia longimana* has tolerance against to salinity with the values of R^2 = 0,85 ve F = 3,775 (p= 0,012), but the number of its specimens decreases while the pH of the seawater increases. Brachyuran crab, *Liocarcinus maculatus* is comparatively found at cold water with the values of R^2= 0,868; F= 4,382 (p= 0,006) yet, it is densely found in sampling sites with high phosphorus.

Discussion

Benthic species are known as indicators for the pollutions observing in marine environments (Del Pilar Ruso *et al*. 2007). The effects of sewage pollution on various benthic communities of the Dardanelles were not specifically studied. This study is on effects of sewage pollution of coastal waters (0-5 m depth) on decapod crustaceans. The shallow coastal waters are known to be dynamic zones because of strong currents and mixing of freshwater and salty water. This variation can be important on organism stress. Yet, pollutant entrance in such sea environments could change environmental dynamics (Venturini *et al*. 2004).

Previous studies are on the effects of sewage pollution on seas and these can negatively affect the environmental factors such as water mass, benthic and pelagic communities sediment, trophic chain (Echavarri-Eransun *et al*. 2007). Furthermore, sewage pollution can change structural characteristics of biodiversity (Terlizzi *et al*. 2002, Fraschetti *et al*. 2005). Benthic assemblages such as polycheatas, bivalves, and crustaceans impact in where domestic pollution since wastewaters bring nitrogen, organic carbon, and phosphorus into sea systems (Chapman *et al*. 1995). Eutrophication has an important affection in destroyting of biodiversity in aquatic environments (Elmanama *et al*. 2006).

Bat *et al*. (2001), found that the abundance of paguroid, *Diogenes pugilator* for the Sinop coast (the southern Black Sea) was 3 individuals at the depth of 1 m where had the amount of organic matter of 2.1%. Yet, we recorded the highest dominance value (Di%=15.20) of this species on the bottom with organic content of 2.40±1.89%. bb

García Raso and Manjón Cabeza (2002), studied the community structure of decapod crustacean found on the coast affected by anthropogenic disturbance in Barbate Bay (the southern Spain) and reported the anomurans most on the shores of detrital structure. Among these, *Diogenes pugilator* was the most dominance with a value of 75.13%. Recently, Saunder *et al*. (2007), recorded a total of 175 specimens of paguroid, *Diogenes avarus* in the area of 0.4 m^{-2} on the Dubai (the united arab emirates) shores are exposed to pollution. Besides, they found the amount of NH_4 as 0.12 for bottoms in where *D. avarus* was dominate.

We reported that *Diogenes pugilator* was the most dominant in spring and in this period the average amount of NH_4 was recorded as 0.91±1.33. During the study of Yüksek *et al*. (2006) regarding the biodiversity of Golden Horn's estuary (the Bosporus) polluted, caridean shrimp, *Crangon crangon* was predominantly found in sandy mud bottom of the 4 depth.

Bustamente *et al*. (2007), carried out a study on macrobenthic communities in Bilbao estuary area (the northern Spain) polluted and found the brachyuran crabs, *Carcinus maenas* (2 ind.), *Pachygrapsus marmoratus* (3 ind.), the pond shrimp, *Palaemon elegans* (1 ind.), and the crayfish, *Procambarus clarkii* (1 ind.). The physical variables and the amounts of pollutants in sea environment are considerable factors in knowing of benthic community structure and the waters polluted have mostly the communities with low species diversity (Morrisey *et al*. 2003). This event is same for Lapseki, Gelibolu, and Çanakkale discharge points. During all sampling period, while only 2 species was recorded for Lapseki discharge, in the other discharge points for Çanakkale and Gallipoli 3 species were found.

Dardanelles is rarely polluted by sewage disposals. Also, a crucial amount of wastewater originated with all the eastern Europe are moved via upper current to the Black Sea, the Bosporus, the Sea of Marmara, and the Dardanelles. Even if the pollutant amounts are low in the areas like bay sheltered (e.g. Kilya Inlet), accumulation of some pollution is reality during no fresh water input (in summer months especially) if discharges of domestic pollution happens (e.g. Lapseki).

Discharge of sewage in Çanakkale center (in the Dardanelles undercurrent Aegean Sea to the Marmara Sea) is releaved about 200 away from the coast, for that, domestic pollution, especially the tide was low at times (summer and autumn). Throughout the year in Lapseki station the high concentrations of NH_4 and NO_3 can be explained with its exposure to organic debris for long-term.

Northeaster wind in the Dardanelles has usually strong impact the formation of the strong currents causing the changes in systems locality has led to suspend of pollutants in the study area. It can be said that especially in summer period when the parts of the urbanizationed area of the Dardanelles at the nights discharges are intense. The effect of these discharges under the affection of strong wind and currents in the Dardanelles will be gone in the morning as possible.

Canonical Discriminant Analysis showed that anionic detergent and phosphorus concentrations are the major factors among all physical and chemical factors considered in the study. Wilks' Lambda was found to be 4.981 (p=0.018) for anionic detergent and 4.977 (p=0.002) for phosphorus respectively. According to discriminant function analysis the physical and chemical constituents measured differ notably in winter compared to other seasons. The changes in several physical and chemical constituents differ due to the fact that summer resorts, seasonal runoff difference, although not examined, and most importantly temperature in the study area.

At the same time, the number of species found in the sampling sites is affected by the pollutant factors in sediment. So, these factors can negatively effect its intensity.

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Çanakkale Boğazı'ndaki dekapod krustase toplulukları üzerine evsel kirliliğin etkileri konusunda yeni bulgular

Özet

Bu çalışma Çanakkale Boğazı'nın 0-5 m derinliklerinde toplanan dekapod krustase toplulukları üzerine evsel kirliliğin etkileri konusunda bilgi sahibi olunmak için gerçekleştirilmiştir. Burada sunulan örnekler Temmuz 2008 ve

Nisan 2009 tarihleri mevsimsel olarak bir SCUBA dalıcısı tarafından yumuşak zeminlerden toplanmıştır. 25 dekapod türüne ait toplam 460 birey bulunmuş ve bu türler arasında keşiş yengeci, *Diogenes pugilator* en yüksek baskınlık değerine (%Di=74.35) sahipti. Çoklu regresyon analizine göre suyun fiziksel, kimyasal ve biyokimyasal değişkenleri ile sediment ve dekapod türleri arasında istatistiksel olarak anlamlı ilişki yoktur.

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