*Article*

# The effects of some domestic pollutants on the cumacean (Crustacea) community structure at the coastal waters of the Dardanelles, Turkey

**A.Suat Ateş**[1], **Tuncer Katağan**[2], **Murat Sezgin**[3], **Hasan G. Özdilek**[4], **Selçuk Berber**[1], **Musa Bulut**[1]
[1]Çanakkale Onsekiz Mart University, Faculty of Marine Sciences and Technology, TR- 17100 Çanakkale, Turkey
[2]Ege University, Fisheries Faculty, TR- 35100 Bornova-İzmir, Turkey
[3]Sinop University, Fisheries Faculty, TR- 57000 Sinop, Turkey
[4]Çanakkale Onsekiz Mart University, Faculty of Engineering and Architecture, TR- 17100 Çanakkale, Turkey
E-mail: asuatates@yahoo.com

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**Abstract**
This study was carried out to determine the effects of sewage pollution on the cumacean assemblages found in the coastal waters of the Dardanelles. The samples were collected by a SCUBA diver between July 2008 and April 2009 and a total of 102 specimens belong to 5 cumacea species, *Bodotria arenosa mediterranea*, *Cumopsis goodsir*, *Cumella limicola*, *Iphinoe maeotica* and *Pseudocuma longicorne* was recorded. The dominant species, *Iphinoe maeotica* has the highest dominance value (36.66%). Multiregression approach resulted in statistically insignificant relationship between physical, chemical and biochemical variables of water and sediment and *Bodotria arenosa mediterranea*, *Cumopsis goodsir*, *Cumella limicola*, and *Iphinoe maeotica*. Based on multiple regression test, a significant relationship with $R^2$ = 92.2%, F= 7.876 and p= 0.000 was found between six water and sediment quality constituents and numbers of *Pseudocuma longicornis* at the stations studied of the Dardanelles. On the other hand, water temperature (β= -0.114; t= -2.811, p= 0.016); sediment organic matter (β= -0.011; t= -2.406; p= 0.033) and water phosphorus ($PO_4$) (β= 0.323; t= 3.444; p= 0.005) were found to be the most important water and sediment parameters that affect *Pseudocuma longicornis*.

**Keywords** Cumacea; crustacean; community; sewage pollution; the Dardanelles; Turkey.

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## 1 Introduction

Every human activity generates wastes in all forms, solid, gaseous, and liquid (Metcalf and Eddy, 2003). Domestic water pollution from industrial, agricultural and urban areas end up in freshwater or brackish water sources, affecting water resources if not properly treated before discharge (Botkin and Keller, 2003). Coastal water pollution is among one of the most crucial water pollution problems since community use such sources for fishing, swimming and other recreational activities. In Turkey, wastewater treatment is a major problem since 45% of domestic wastewater is discharged into seas (TSI, 2010). Despite the fact that industrial water pollution is not a major problem in Turkey, quantity of domestic wastewater has increased dramatically over the past few decades due to expansion of urbanization in Turkey. Turkish seas are connected via two sea straits, named Bosporus and Dardanelles. Dardanelles connects the Aegean Sea and the Sea of Marmara. Dominant water flow is from Black Sea to the Sea of Marmara and then to the Aegean. However, coastal urban areas are main concern due to their untreated wastewater discharges followed inputs from ships. It is reported that approximately 50000 ships pass through the Dardanelles every year. Coastal zone, however, are more polluted with wastewaters disposal from small communities followed by ship activities. The effect of untreated wastewater disposal on coastal zone is in general observed as eutrophication. With the effect of dry period and ambient air temperature, eutrophication is observed especially in August. However, dilution of water pollution with respect to higher precipitation and therefore runoff do not cause eutrophication in the winter months, especially in January.

Crustaceans are mostly used as bioindicators and biomonitors in different aquatic ecosystems and they are known as bioindicators in polluted areas (Rinderhagen et al., 2000). Sewage pollution impacts benthic organisms. Changes due to pollution are determined by community structure of benthic fauna primarily (Arasaki et al., 2004). Although some temporary changes in organic matter are observed due to sewage pollution at initial stages, sensitive species soon leave the polluted zone if pollution is a persistent problem (Bat et al., 2001). To determine the distribution of indicator species is crucial in maping of pollution gradients (Corbera and Cardell, 1995). Many study on the subject were carried out on polychaetes and molluscs (Bellan, 1967).

Crustaceans are the first of sensitive livings among benthic assemblages affected by quantity of sewage pollution (Bat et al., 2001; Del Vals et al., 1998; Guerra-García and García-Gómez, 2004). Physical environmental factors as well as pollutant concentrations are important in determination of benthic community and low biodiversity is a fact on sewage pollution affected areas in coastal zones (Morrisey et al., 2003). Sewage pollution’s effects on crustaceans in the Mediterranean ecosystem are found in the following studies. Del Val et al. (1998) and Guerra-García and García-Gómez (2004) studied the effects of sewage pollution on crustaceans found in soft bottoms of two different littoral systems of Cadiz Bay (the eastern Atlantic) and of Ceuta Harbour (the Gibraltar Strait) respectively. Additionally, García Raso and Manjón Cabeza (2002) determined the effects of sewage pollution on decapod crustaceans in the upper-infralittoral zone of Barbate Coast (the southern Spain). Recently, Hamouda and Abdel-Salam (2010) studied the distribution models of macrobenthic communities including cumaceans found in Abu-Qir Bay (Alexandria, Egypty) in where organic pollution occurs. Extreme organic pollution causes to disappear of sensitive species in the environment (Hamouda and Abdel-Salam, 2010).

Bat et al. (2001) mentioned effects of domestic wastewater discharge on several crustacean species at the depths of 0.5-1 m on the coast of Sinop Harbour (the southern Black Sea, Turkey). Albayrak et al. (2006) sampled four different locations in the northern Marmara Sea in order to determine levels of pollution due to organic material discharges. Tuğrul-İçemer and Koşun (2003) carried out a study underlining that benthic community structure under sewage pollution in Antalya Bay (the eastern Mediterranean). Similar to our study, Corbera and Cardell (1995) studied indicative cumaceans affected by eutrophication in the soft bottoms of Barcelona coast (the southern Spain).

Despite of several studies (Tuğrul-İçemer and Koşun, 2003 for the Mediterranean Sea, Kocataş et al., 1988 for the Aegean Sea, Albayrak et al., 2006 for the Sea of Marmara, Okuş et al., 1996 for the Bosporus, Bat et al., 2001 for the Black Sea) regarding the effects of pollution on benthic communities of the Turkish coast occurred, there is no research indicated the effects sewage pollutants on the structure of macrozoobenthic communities in relation to environmental conditions in the Dardanelles. The Dardanelles is a long, narrow, and shallow strait. Saros Bay is located in the North part of the Dardanelles is known as an important fisheries activity area and it is expressed that water coming from the Black Sea is discharged into the northern Aegean and the Saros after passing the Dardanelles. Therefore, the end point of the water flow from the Black Sea is this region. Any type of pollution is highly expected to accumulate in the region.

The aim of this study is to determine the effects of sewage pollution on the cumacean assemblages on soft bottoms of the Dardanelles.

## 2 Material and Methods

### 2.1 Sample collection, study area and field measurements.

Study area includes 8 sampling points, 4 of them are located on the Anatolian Coast and other 4 are located on the European Side. GPS coordinates of the sampling stations are: 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).
Samples of cumacean at the depths of 0 to 5 m were collected from three different transects (depth counters of 0.5, 2 and 4 m) using a quadrate system of 30x30 cm by a Scuba diver and preserved in buffered formalin. Samplings were carried out on July 17, 2008, November 12, 2008, February 16, 2009 and April 29, 2009, seasonally.

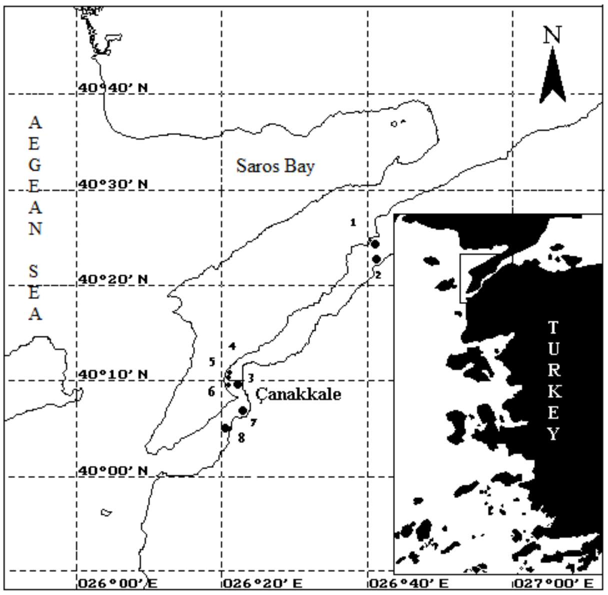


**Fig. 1** Map of the study area showing the sampling stations (1: Gelibolu, 2: Lapseki, 3: Çanakkale, 4: Kilya Inlet, 5: Eceabat, 6: Kilitbahir 7: Kepez Harbour, 8: Dardanos).

### 2.2 Sediment type of sampling sites

Sampling depths were selected in localities that pouring down domestic waste to the marine environment. For the reference stations, the same sampling depths were adopted. Hence, the depth of each sample showed a different structure of the bottom. The bottom of 2-5 m of Kilitbahir sampling station is partly covered by *Mytilus galloprovincialis*. Kilya station is silty. Eceabat station (2-4 m) is sandy bottom with meadows, *Zostera marina*. While Lapseki sampling site has fine sand, Çanakkale sampling site is partly covered by algae and coarse sand with rocks. Kepez Harbour is dominated by mytilid bivalve, *Mytilus galloprovincialis* at depth of 4 m. Dardanos sampling site is covered with fine sand of meadows, *Zostera marina.* Sediment organic matter was determined by 550 °C incineration of washed known weight of sediment samples (generally 50 grams) for two hours. The difference between incinerated and raw sediment weight provided percent organic matter. Sediment organic matter was determined by the high temperature oxidation method adopted by Craft et al., 1991. In addition to loss of ignition at 550 °C using furnace, organic carbon and total nitrogen were also determined by the high temperature oxidation method. Loss of ignition method requires a weighed dry material and slowly increasing furnace set up 550 °C and waiting generally 1 to 2 hours at this temperature. TOC analyzers are gaining in favour because of short test periods. Clean sand sample was also tested to compare with results obtained from sediment samples.

**2.3 Sea water quality parameters**

Dissolved oxygen, water temperature, electrical conductivity, pH and salinity were measured using YSI 556 model MPS on site. Water samples were collected using dark color 1 liter clean glass bottles. Ammonia, nitrate, nitrite, Biological Oxygen Demand, Chemical Oxigen Demand, and anionic detergents were determined using Standard Methods (Apha Awwa, 2005). Moreover, water organic constituents were determined using Hach-5000 spectrophotometer. There replicates were tested for all parameters and statistically no difference were found after data evaluation. Quality control was ensured when testing parameters in laboratory.

**2.4 Ecological data analyses**

Triocular stereo microscope was used to determine of specimens belonging to cumaceans found from the study area. The specimens of cumacean were defined based on the study of Ledoyer (1965). To elucidate the community structure, Soyer (1970)'s frequency index (¦f%), Bellan-Santini (1969)'s quantitative dominance index (Di%), Shannon and Weaver (1949)'s diversity index (H´) as well as its evenness component (J´) and Bray and Curtis (1957)'s similarity index were calculated. The community structure was investigated by group-averaging cluster analysis based on the Bray and Curtis (1957). In calculating of (Shannon and Weaver, 1949)'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

$$f = (m/M) \times 100$$

where, $m$ is number of stations where species of concern exists, and $M$ is number of all stations.

The dominance index of a certain species was estimated by $D_i = (m/M) \times 100$, 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

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

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 and Curtis (1957)'s similarity index is

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

**2.5 Statistical data analyses**

Variance analyses were completed to see whether there are statistical differences between sampling sites and sampling time (seasons). These analyses were completed using SPSS 10.0. Moreover, physical and chemical water quality parameters were tested in order to see which ones are correlated. Friedmann test was adopted to see cumacea species distribution with respect to 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), and $S_j$ is standart deviation of the data set.

All collected parameters were evaluated using MANOVA (multiple analysis of variance). The correlation between species compositioin and polluants was evaluated using a Spearman Correlation. The relationship between the physico-chemical parameters and domestic pollutants in sea water was identified by the method of canonical discriminant analysis.

## 3 Results

### 3.1 Environmental conditions

Seasonal mean dissolved oxygen (DO) concentration was computed to be 7.13 (±0.59) mg $L^{-1}$. Çanakkale was found to have the highest DO concentration (9.79 mg $L^{-1}$) in April 2009. Lapseki discharge site was found to have the lowest DO value (3.68 mg $L^{-1}$) in July 2008. Seasonal average value of salinity was computed to be 25.52 (±1.30) ‰ for all sampling sites and times. Dardanos discharge sampling site was found to have the highest salinity value (30.5‰) in November 2008. Lapseki discharge sampling site was found to have the lowest salinity value (23.6‰) in April 2009. Mean sea water temperature among all stations and sampling times was determined to be 16.02 (±5.82) °C for sampling area. The highest sea water temperature (26.77 °C) belongs to Kilya reference sampling site in July 2008 despite the fact the lowest (8.87 °C) was recorded at Gelibolu discharge site in February 2009 (Table 1). Table 1 includes all the physical and chemical data measured in the sampling area. Based on two-way ANOVA, only sampling times was found to create differences in DO, pH and sea water temperature statistically. However, both sampling times and sampling sites were found to create statistical differences in salinity and electrical conductivity according to two-way analysis of variance (MANOVA).

### 3.2 Water pollutants ($NH_4^+$, $NO_3^-$, $NO_2^-$, $PO_4^{-3}$, sediment organic matter and anionic detergent)

Ammonia ($NH_4^+$) concentration of all sampling times and locations was computed as 35.94 (±50.26) mg $L^{-1}$ on average. The highest ammonia levels belong to Çanakkale and Lapseki discharges as 168 and 166 mg $L^{-1}$ in July 2008 respectively. Kilya and Kepez harbour sites were detected to have the very low ammonia concentration as 0.06 mg $L^{-1}$ (both) in April 2009. Moreover, Kilya reference site was found to be the cleanest in terms of $NH_4^+$ as 0.05 mg $L^{-1}$ in February 2009 (3.68 mg $L^{-1}$) in July 2008. Nitrate ($NO_3^-$) concentration of all sampling times and locations was computed as 0.30 (±0.22) mg $L^{-1}$ on average. The highest nitrate level (0.85 mg $L^{-1}$) was detected at the Lapseki discharge in November 2008. Çanakkale and Eceabat discharges were found to have the lowest nitrate concentration as 0.01 mg $L^{-1}$ (both) in February 2009. Mean nitrite ($NO_2^-$) level of all sampling times and locations was computed as 0.057 (±0.04) mg $L^{-1}$. The maximum nitrite level was measured at the Gelibolu discharge as 0.158 mg $L^{-1}$ in February 2009. Interestingly Kepez harbour reference station was found to have a high level of nitrite as 0.151 mg $L^{-1}$ in February 2009. Dardanos discharge site was found to have the lowest nitrite concentration of 0.004 mg $L^{-1}$ in July 2008.

Mean sediment organic matter (percent SOM) of all sampling times and locations was computed as 2.85 (±2.16) %. The maximum SOM level was found at Lapseki discharge as 9.86% in April 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. As expected. Kilitbahir site was recorded with the lowest SOM as 1.75 %. Mean anionic detergent of all sampling times and locations was computed as 0.04 (±0.02) mg $L^{-1}$. The highest detergent value. 0.105 mg $L^{-1}$. was measured at Gelibolu discharge site in July 2008. The lowest amount of detergent (0.011 mg $L^{-1}$) was found at Kepez harbour probably due to the fact that there is a wastewater treatment plant. Kepez and Kilya reference sites. Average anionic detergent concentration was computed to be 0.63 and 0.62 mg $L^{-1}$ at Gelibolu and Lapseki discharge sites to be the highest among all sampling stations taking into account only of individual sampling sites not the individual sampling time (Table 2).

**Table 1** Dissolved oxygen, seawater temperature, seawater salinity, pH, electrical conductivity values measured at study site.

| Sampling Period | July 2008 | | | | November 2008 | | | | February 2009 | | | | April 2009 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stations | $O_2$ mg $L^{-1}$ | T (°C) | S (‰) | pH | $O_2$ mg $L^{-1}$ | T (°C) | S (‰) | pH | $O_2$ mg $L^{-1}$ | T (°C) | S (‰) | pH | $O_2$ mg $L^{-1}$ | T (°C) | S(‰) | pH |
| Çanakkale (D) | 4.19 | 23.7 | 23.3 | 8.21 | 5.00 | 15.25 | 25.6 | 8.32 | 9.63 | 9.18 | 27.8 | 5.30 | 9.79 | 14.26 | 24.4 | 7.07 |
| Lapseki (D) | 3.68 | 24.57 | 22.6 | 8.15 | 3.34 | 15.70 | 24.6 | 8.25 | 9.65 | 9.31 | 27.4 | 6.40 | 8.72 | 13.68 | 23.6 | 6.85 |
| Gelibolu (D) | 5.58 | 25.03 | 22.8 | 8.33 | 5.56 | 16.17 | 25.5 | 8.51 | 9.61 | 8.87 | 27.6 | 7.48 | 8.13 | 13.10 | 24.3 | 6.50 |
| Kilya Inlet (R) | 8.46 | 26.77 | 23.1 | 8.53 | 5.90 | 16.30 | 25.7 | 8.55 | 9.25 | 9.24 | 26.5 | 7.55 | 7.95 | 13.50 | 23.3 | 6.48 |
| Eceabat (D) | 7.40 | 25.60 | 22.9 | 8.39 | 6.01 | 16.01 | 25.5 | 8.46 | 9.56 | 9.24 | 27.4 | 8.09 | 8.90 | 13.31 | 24.2 | 6.52 |
| Kilitbahir (D) | 5.16 | 25.1 | 23.1 | 8.31 | 5.68 | 16.37 | 25.6 | 8.33 | 9.20 | 9.12 | 27.6 | 8.79 | 8.90 | 13.23 | 24.3 | 7.05 |
| Kepez Harbour (R) | 5.14 | 24.39 | 23.5 | 8.30 | 5.28 | 16.22 | 26.1 | 8.45 | 5.68 | 9.65 | 28.3 | 5.44 | 8.65 | 14.10 | 24.8 | 6.74 |
| Dardanos (D) | 6.49 | 24.36 | 28.1 | 8.44 | 5.83 | 16.07 | 30.5 | 8.70 | 7.94 | 9.61 | 28.3 | 5.13 | 8.04 | 15.75 | 28.6 | 6.88 |

DO (mg $L^{-1}$): Dissolved oxygen. T (°C): Seawater temperature. T (‰): Seawater salinity. pH: Activity of Hidrojen ion. EC (mS/cm): Conductivity.

**Table 2** Ammonia, nitrate, nitrite, sediment organic matter, and anionic detergent measured measured during the study.

| Sampling period | July 2008 | | | | | November 2008 | | | | | February 2009 | | | | | April 2009 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stations | $NH_4$ | $NO_3$ | $NO_2$ | OM | AD | $NH_4$ | $NO_3$ | $NO_2$ | OM | AD | $NH_4$ | $NO_3$ | $NO_2$ | OM | AD | $NH_4$ | $NO_3$ | $NO_2$ | OM | AD |
| Çanakkale (D) | 168 | 0.08 | 0.012 | 8.22 | 0.058 | 56.1 | 0.76 | 0.079 | 16.7 | 0.078 | 48.3 | 0.01 | 0.105 | 22.5 | 0.056 | 0.72 | 0.16 | 0.018 | 50.2 | 0.048 |
| Lapseki (D) | 166 | 0.4 | 0.031 | 14.1 | 0.067 | 121 | 0.85 | 0.092 | 13.7 | 0.053 | 7.8 | 0.74 | 0.057 | 22.5 | 0.083 | 0.13 | 0.15 | 0.014 | 98.6 | 0.045 |
| Gelibolu (D) | 1.47 | 0.32 | 0.113 | 8.75 | 0.105 | 1.89 | 0.60 | 0.041 | 34.9 | 0.057 | 1.62 | 0.15 | 0.158 | 13.1 | 0.049 | 0.41 | 0.22 | 0.036 | 45.0 | 0.039 |
| Kilya Inlet (R) | 72.4 | 0.28 | 0.039 | 11.4 | 0.028 | 11.6 | 0.34 | 0.028 | 12.9 | 0.021 | 0.05 | 0.42 | 0.074 | 15.1 | 0.014 | 0.06 | 0.18 | 0.034 | 56.9 | 0.014 |
| Eceabat (D) | 33 | 0.11 | 0.036 | 12.3 | 0.066 | 52 | 0.12 | 0.047 | 28.5 | 0.037 | 77.1 | 0.01 | 0.092 | 11.0 | 0.061 | 3.90 | 0.31 | 0.047 | 44.3 | 0.041 |
| Kilitbahir (D) | 33.7 | 0.02 | 0.031 | 5.50 | 0.019 | 13.5 | 0.15 | 0.038 | 18.9 | 0.029 | 3.5 | 0.17 | 0.023 | 18.8 | 0.044 | 1.93 | 0.41 | 0.043 | 26.6 | 0.033 |
| Kepez Harbour (R) | 14 | 0.28 | 0.074 | 16.2 | 0.024 | 12.9 | 0.11 | 0.096 | 19.4 | 0.027 | 16 | 0.20 | 0.151 | 20.1 | 0.013 | 0.06 | 0.60 | 0.036 | 46.3 | 0.011 |
| Dardanos (D) | 131 | 0.32 | 0.004 | 72.9 | 0.027 | 97.3 | 0.41 | 0.034 | 28.6 | 0.026 | 2.71 | 0.40 | 0.118 | 33.2 | 0.018 | 0.40 | 0.20 | 0.037 | 65.8 | 0.014 |
| Average and Standart Deviation | 77.4 (68.3) | 0.23 (0.14) | 0.043 (0.035) | 18.7 (22.2) | 0.05 (0.03) | 45.8 (44.2) | 0.42 (0.29) | 0.057 (0.028) | 21.7 (7.99) | 0.041 (0.02) | 19.64 (23.61) | 0.26 (0.25) | 0.10 (0.05) | 19.5 (6.96) | 0.04 (0.03) | 0.91 (1.33) | 0.28 (0.16) | 0.033 (0.011) | 54.2 (21.2) | 0.031 (0.015) |

*****: All variabales are presented as mg L-1 and OM: sediment organic matter (‰)

**Table 3** Total number of specimen belong to species found, values of dominance (Di%), and of seasonal abundance (f%) of cumaceans in the study area.

| Species | Kilitbahir | Eceabat | Kilya Inlet | Gallipoli | Lapseki | Canakkale | Kepez Harbour | Dardanos | Total specimen (Σ) | Dominance (Di%) | Seasonal frequency (f%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Bodotria arenosa mediterranea* | 0 | 0 | 0 | 1 | 5 | 4 | 0 | 3 | 13 | 12.74 | 100 |
| *Cumopsis goodsir* | 2 | 0 | 0 | 0 | 10 | 0 | 0 | 4 | 16 | 15.68 | 75 |
| *Cumella limicola* | 6 | 9 | 1 | 2 | 13 | 0 | 4 | 1 | 36 | 35.29 | 100 |
| *Pseudocuma longicorne* | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 3.92 | 50 |
| *Iphinoe maeotica* | 0 | 1 | 11 | 5 | 14 | 0 | 0 | 2 | 33 | 32.35 | 100 |

### 3.3 Faunal composition

A total of 102 specimens belong to 5 cumacean species in the soft bottoms of the depths between 0 and 5 m of 8 different stations (6 discharges, 2 references) in the Dardanelles was reported. Among these species *Cumella limicola* has the highest dominance value of 35.29%. This species was followed by *Iphinoe maeotica* with value of 32.35% and *Cumopsis goodsir* (Di%=15.68). The lowest value (Di%=3.92) is belong to *Pseudocuma longicorne*. The annual values of dominance of all cumaceans are presented in Table 4. All cumacean species found here appeared to constitute permanent components of the fauna (with f% values >50). In winter 2009, there was a highest number of individuals (n=48), while *Cumella limicola* and *Iphinoe maeotica* were observed in this period with a maximum number of individuals (N=17).

The highest number of specimens was found at Lapseki discharge station (42 specimens), and the lowest value was 4 at Çanakkale discharge and Kepez Harbour site (Fig. 2; Table 3). In the study area, the maximum species (5) was recorded in Autumn 2008 and Winter 2009 seasons. At least species was observed in Summer 2008 with 3 species. The highest number of individual (58 specimens) was recorded in winter 2009. This season was followed by Spring 2009 with 34 specimens and Autumn 2008 15 specimens. The lowest value (5 specimens) was reported in summer 2008 (Fig. 3).

The diversity index values (H´) at the sampling stations ranged between 0.46 and 1.91. The evenness index (J´) values belong to the stations mainly ranged between 0.46 and 0.95 (Fig. 4). H´ values for Çanakkale and Kepez Harbour stations couldn't be calculated because only single species was recorded from the stations cited. The seasonally values of the equitability and diversity indices showed a similar development and the diversity (H´) was highest in February 2009. The diversity index values (H´) in sampling seasons ranged between 0.4 and 0.68. Moreover, the evenness index (J´) values according to the seasons mainly ranged between 0.80 and 0.98 (Fig. 5).

These results show that cumaceans were generally more abundant in the winter and spring as compared to other seasons. According to results of the Bray and Curtis (1957)'s similarity index, the seasons Spring and Winter 2009 shared the same similarity groups with a value of 81.26%. on the one hand. the similarity value was 69.63% between winter-spring 2009 group and Autumn 2008 (Fig. 6).

Bray and Curtis (1957)'s similarity analysis shows that Gelibolu, Lapseki, Dardanos discharge sites and Kilya Inlet reference station shared the same group and the similarity value for these stations is approximately 66%. The highest similarity was observed between the Eceabat discharge station and Kepez Harbour reference station with a value of 69.74% (Fig. 7).

Calculation of Spearman's rank correlation coefficient ($r_s$) (Zhang, 2012a, b) between biotic (species' number) data and domestic pollutants ($NH_4$, $NO_3$, $NO_2$, organic matter in sediment, and anionic detergent) parameters revealed a statistically non-significant correlation ($p < 0.05$). A positive correlation is observed between the cumacean fauna and the pollutants, $NO_3$ ($r_s = 0.72$; $p < 0.05$), organic matter ($r_s = 0.43$; $p < 0.05$), $NH_4$ ($r_s = 0.31$; $p < 0.05$) and anionic detergent ($r_s = 0.23$; $p < 0.05$).

*Bodotria arenosa mediterranea* was found to be statistically indifferent at stations based on Friedman test ($F_D = 7.56 < \chi^2_{(0.05;\ 7)} = 14.1$). *Cumopsis goodsir* was also indifferent in terms of numbers identified by sampling stations according to Friedman test result ($F_D = 4{,}67 < \chi^2_{(0.05;\ 7)} = 14.1$). *Cumella limicola* was determined to be indifferent in terms of numbers grouped by sampling stations after completing Friedman test ($F_D = 8{,}33 > \chi^2_{(0.05;\ 7)} = 14.1$). *Pseudocuma longicorne* also showed no statistical difference among sampling stations based on Friedman test result ($F_D = 2{,}33 < \chi^2_{(0.05;\ 7)} = 14.1$). *Iphinoe maeotica* was also found not statistically different based on numbers according to Friedman test ($F_D = 6{,}69 < \chi^2_{(0.05;\ 7)} = 14.1$). In summary, Friedman test result indicates that the stations and seasons have no effect on number of specimens belong to the species indicated above.

Multivariate non-parameteric tests also confirmed that no statistically significant results exists. *Bodotria arenosa mediterranea*, *Cumopsis goodsir*, *Cumella limicola*, *Iphinoe maeotica* species were found to have no statistical relevance with water and sediment quality parameters examined (organic constituents of water) based upon multiple linear regression. Besides seawater temperature ($\beta$= -0.114; t= -2.811 (p= 0.016)); quantity of organic matter in sediment ($\beta$= -0.011; t= -2.406 (p= 0.033)) was found to be the most important water and sediment parameters that affect the the number of individual belong to *Pseudocuma longicornis*. In addition, water temperature and organic matter in sediment were determined to have negative impact on number of individuals belong to *Pseudocuma longicorne.*

Although not found statistically significant, at least one parameter examined (electrical conductivity pH, OM, AD, temperature, and salinity in water (spectorophotometrically measured 254 nanometers), sediment water content (%), $NO_3^-$, $NH_4^+$ was found to be related with *Bodotria arenosa mediterranea*.

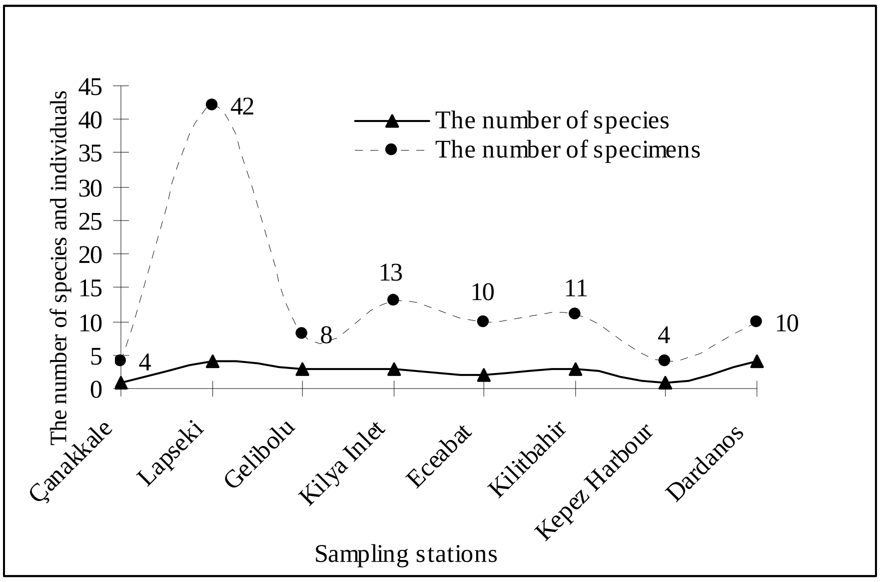


**Fig. 2** The number of species and individuals recorded at the sampling stations.

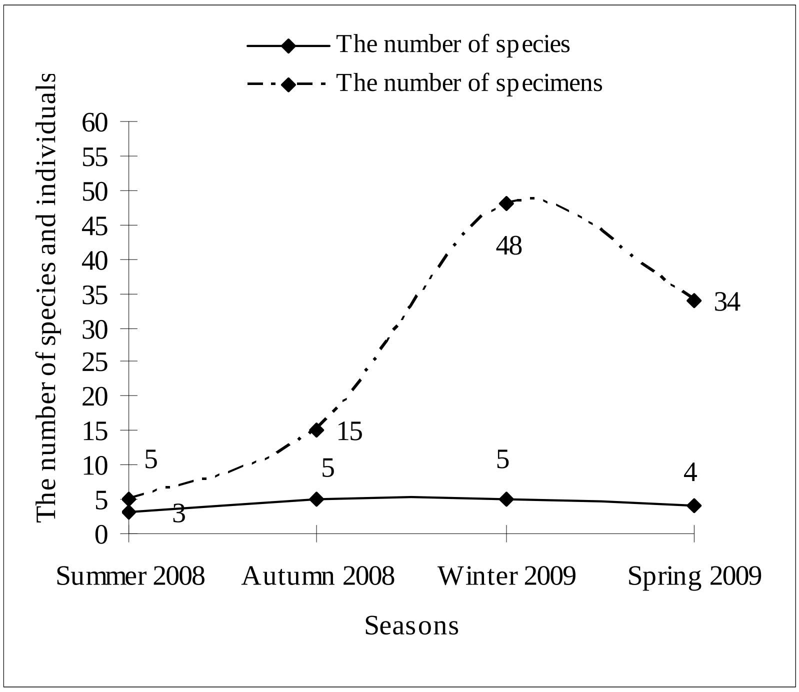


**Fig. 3** The number of species and individual found during the sampling seasons.

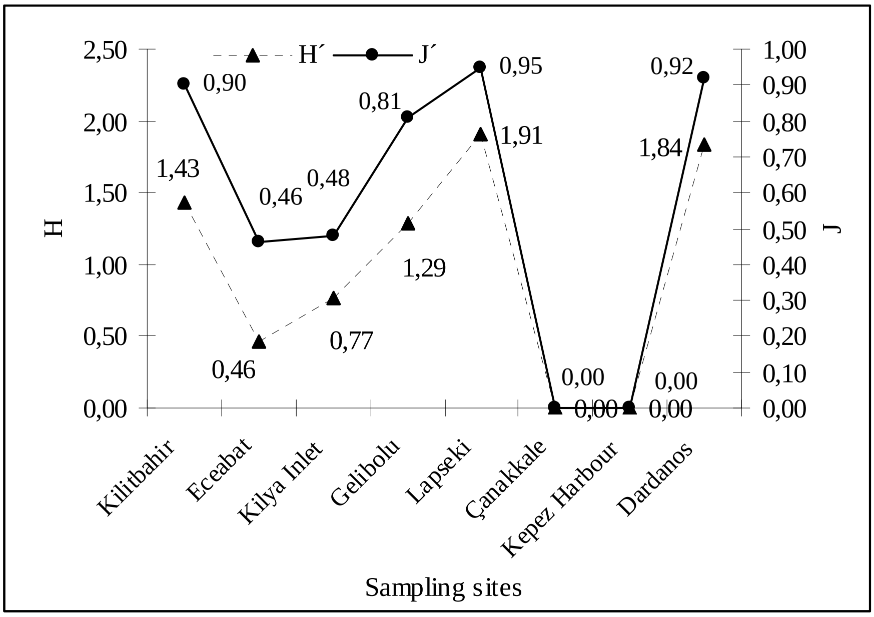


**Fig. 4** Values of the diversity (H´), evenness (J´) at the sampling points.

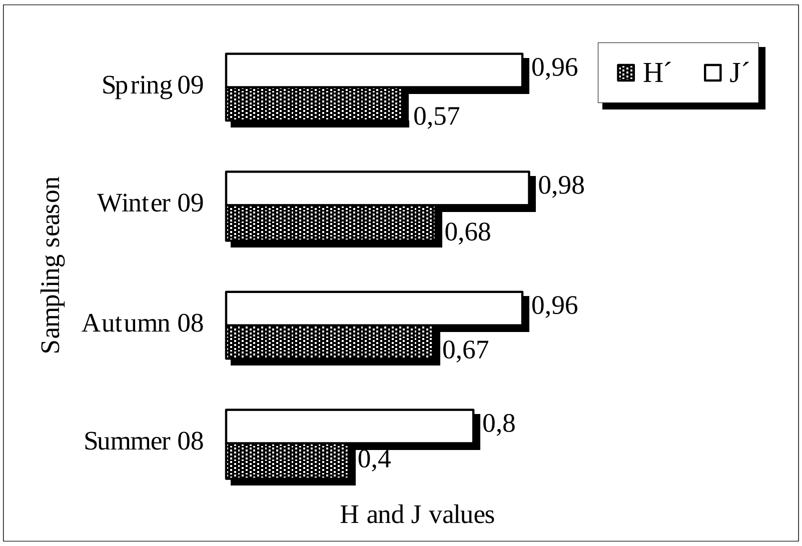


**Fig. 5** Values of the diversity (H´), evenness (J´) in the seasons.

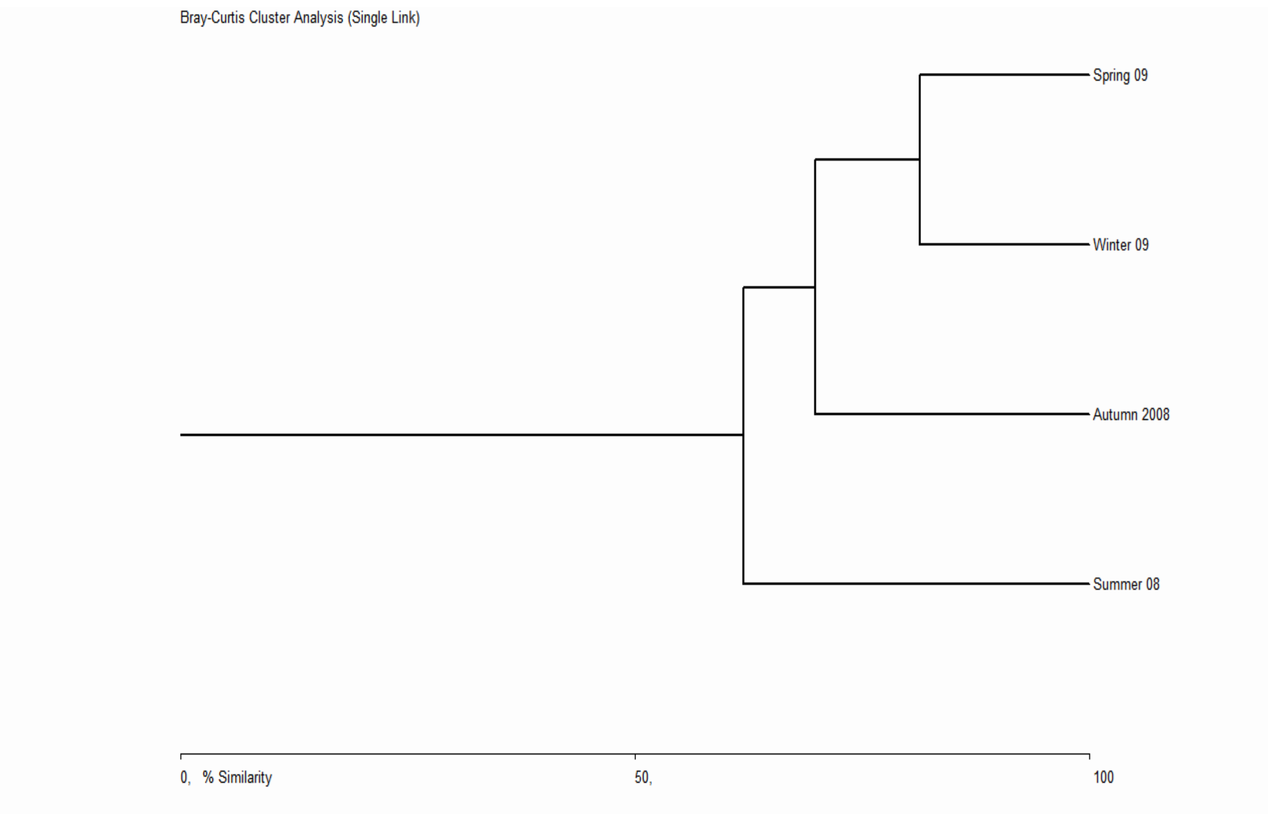


**Fig. 6** Similarity of the cumacean community in the sampling seasons (Bray-Curtis index).

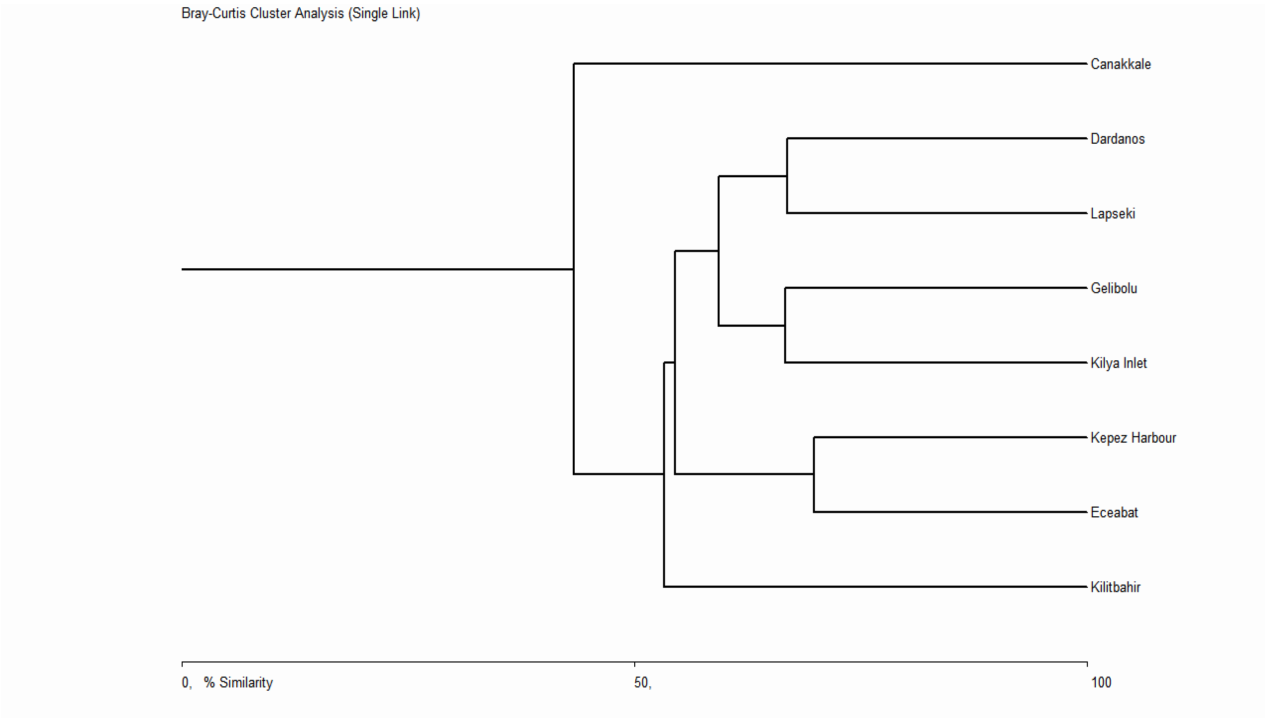


**Fig. 7** Similarity of the cumacean community at the sampling stations (Bray-Curtis index).

## 4 Discussion

Benthic assemblages are widely used as indicators and for the detection of human impacts on marine environments (Del Pilar Ruso et al., 2007). In this study, the consequences of domestic sewage discharge from different localities of the Dardanelles, which connects the Black Sea to the Mediterranean Sea and a part of Turkish straits system, and reference sites, which have natural back sides and have less pollution were examined. The effects of raw sewage discharged at different communities situated on the strait on coastal macrobenthic communities were not specifically studied. With this detailed study, the effects of sewage disposals released from communities (namely Eceabat (population 5,498 according to 2007 census). Gallipoli (population 31,746 according to 2007 census), Lapseki (population 10,612 according to 2007 census) and Çanakkale (population 86,544 based on 2007 census), which is the capital of Çanakkale Province and one municipality (Kepez population is approximately 10,000) and one village (Kilitbahir, population is approximately 1,000)) and one natural (Kilya Inlet) were examined. In addition to these, Dardanos is a summer resort and domestic sewage is also discharged there. Kepez is the only community that has been served with a wastewater treatment plant since 2007. The sampling site at Kepez is also next to the harbour and is affected by strong surface current. Effects of pollution of coastal waters (0-5 m depth) from domestic wastewater on cumacea species were studied. As known, shallow coastal waters and estuarines are dynamic zones because of strong waves and mixing of freshwater and salty water. This natural variation may cause main reason of organism stress. Yet, nutrients, organic matter and pollutant entrance in such environments might change environmental circumstances (Venturini et al., 2004).

Present literature about sewage pollution on seas underline that environmental factors (water mass, benthic and pelagic communities sediment, trophic chain) are affected differently with diverse discharges (Echavarri-Erasun et al., 2007). Sewage pollution can change structural integrity of biodiversity (Terlizzi Et al., 2002). Several benthic groups such as macroalgae, tunicates, poriferas, bivalves, and crustaceans impact in where domestic pollution is a reality. Moreover, the present populations of these organisms decline with respect to time (Chapman et al., 1995), since domestic wastes bring nitrogen, organic carbon, and phosphorus into aquatic systems. In other words, sewage pollution is a mixture of many types of toxic matter and its harmfully effects the biota. Eutrophication has an important role in destruction of biodiversity in aquatic environments (Elmanama et al., 2006).

With the effect of pollution, dominant cumacean species are reported between 5 and 13 m as *Bodotroia pulchella* and *Pseudocuma longicorne* and *Pseudocuma simile* and *Iphinoe armata* below 20 m by Corbera and Cardell (1995). In addition, sediment organic matter was found to be between 0.6 and 1.1% in Barcelona, Spain (Corbera and Cardell, 1995) also reported that *Iphinoe rhodaniensis* has the highest biomass value and its existence is triggered with the increase of pollution. In our study, reported cumaceans are *Bodotria arenosa mediterranea*. *Iphinoe maeotica*, and *Pseudocuma longicorne*. These species were found in winter season when sediment organic matter is 1.95±0.69%. Moreover, these species were found dominant at the depths between 0 and 2 m. The most dominant species were found to be *Cumella limicola* (Di=35.29%) and *Iphinoe maeotica* (Di=%32.35).

Hamouda and Abdel-Salam (2010) reported two cumaceans, *Bodotria scorpioides* and *Iphinoe serrata* on the coasts of Abu-Qir Bay (Alexandria, Egypt) in where organic matter is observed. *Iphinoe serrata* was the dominant species with its dominance value of 97.75%. The structure of cumacea community in this study are affected more by nitrite content in seawater.

The physical environmental factors and the concentrations of pollutants in seawater are important in determining of benthic community structure and in polluted areas the community has a low species diversity (Morrisey et al., 2003). This status is same for Lapseki, Gallipoli, and Çanakkale discharges. While no species was recorded for Lapseki discharge in summer sampling, the same station has 21 cumacean specimens for spring season. Discharge points for Çanakkale and Gallipoli, while these values for summer, spring is 0 to 0 and 3 and 5 respectively. This can be explained with the increase in the number of specimens in the stations cited owning to excessive precipitation during spring period. Due to precipitations observed during spring the input of freshwater carried by stream constituted the pollution in Lapseki sampling point caused the dilution of local contaminants.

The Dardanelles is rarely polluted by urbanization and industrial facilities where are located its around because of Çanakkale has the lowest population density in Marmara Region up to date. Also, an important amount of wastewater originated with all eastern Europe, a part of the middle Europe, and the group of independent states are unpurifiedly moved by upper current to the Black Sea, the Bosporus, the Sea of Marmara, and the Dardanelles. Even if the pollutant concentrations are low in the areas such as bay sheltered (example of anionic detergent as Kilya Inlet, the average annual; 0.019±0.005 mg/L), accumulation of some pollution is reality during no fresh water input (in summer months especially) if discharges of domestic pollution happens (e.g. Lapseki).

Deep discharge of sewage of Çanakkale province center (in the Dardanelles undercurrent Aegean Sea to the Marmara Sea), domestic pollution, especially the tide was low at times (summer and autumn), the inlets and small bays in areas where pollutant accumulation is possible. Wastewater is less dense than sea water (have lower specific gravity), but without any particular stream impacts directly related to the horizontal surface layer can be transported away from the discharge point. Denitrification via nitrite and nitrate in water and nitrous oxide are converted (Sawyer et al., 2003).

Lapseki discharge points throughout the year than other stations in the $NH_4^+$ and $NO_3^-$ the reason why the highest value of the accumulated sediments in the long term can be connected to the organic debris. The most important element of livings on the basis of only the nitrogen and phosphorus in terms of nitrate nitrogen, which is a derivative of the Dardanelles, nor seasonal sampling locations differ in terms of what can be said. The organic matter content of water in the Black Sea and the Marmara and Aegean probably varies with the convection dynamics. North-east wind is generally strong, mistral wind and south due to the strong currents of change in systems locality has led to removal of pollutants from the study area. Based on our observations we can say that, especially in summer time when parts of the residential area of the strait at night discharges are intense. The impact of these discharges under the influence of wind and currents in the Strait will be gone in the morning as possible, but it was a part of sunlight during the discharge of pollution that cannot be intense.

Canonical Discriminant Analysis showed that anionic detergent concentration is the main factor among all physical and chemical factors examined in the study. Wilks' Lambda was found to be 4.981 (p=0.018) for anionic detergent. Discriminant function analysis showed that physical and chemical constituents measured in this study differ notably in winter compared to other seasons. It is hard to tell, however, that whether temperature or fresh water inputs to the system or both together, equally, cause differences among the parameters examined. It could be concluded that change in some 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. With the expected population change, increase in some physical and chemical water quality parameters will probably be experienced in the future if pollution control measures would not be taken beforehand.

However, study in discharge points in recorded number of species than the expected due to the reason that the pollutant factors of sediment in water and strong currents and wind action because of its intensity negatively affecting absence is considered.

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**References**

Albayrak S, Balkıs H, Zenetos A, et al. 2006. Ecological quality status of coastal benthic ecosystems in the Sea of Marmara. Marine Pollution Bulletin, 52: 790-799

Apha Awwa 2005. 21st Edition of Standard Methods for the Examination of Water and Wastewater (Eaton A D, Clesceri, LS, Rice EW, Greenberg AE, eds). American Public Health Association, Washington, USA

Arasaki E, Muniz P, Pires-Vanin AMS. 2004. A Functional Analysis of the Benthic Macrofauna of the São Sebastião Channel (Southeastern Brazil). Marine Ecology, 25 (4): 249-263

Bat L, Akbulut M, Sezgin M, Çulha M. 2001. Effects of sewage pollution on the structure of the community of *Ulva lactuca*, *Enteremorpha linza* and rocky macrofauna in Dışliman of Sinop. Turkish Journal of Biology, 25: 93-102

Bellan G. 1967. Pollution et peuplements benthiques sur substrat meuble dans la région de Marseille Première partie. Rev. Int. d'Océa. Méd, 6-7: 53-87

Bellan-Santini D. 1969. Etudefloristuque et faunistuque de quelquespeuplements infralittoraux de substrat rocheus. Recueil des Travaux de la Station Marine d'Endoume, 41: 237-298

Botkin DB, Keller EA. 2003. Environmental Science: Earth as a Living Planet (4th Edition). John Wiley and

Sons, Inc, Hoboken, NJ, USA

Bray JR, Curtis JT. 1957. An ordination of the upland forest communities of South Wisconsin. Ecological Monographs, 27: 325-347

Chapman MG, Underwood AJ, Skilleter GA. 1995. Variability at different spatial scales between a subtidal assemblage exposed to the discharge of sewage and two control assemblages. Journal of Experimental Marine Biology and Ecology, 189(1-2): 103-122

Corbera J, Cardell MJ. 1995. Cumaceans as indicators of eutrophication on soft bottoms. Scientia Marina, 59 (1): 63-69

Craft CB, Seneca ED, Broome SW. 1991. Loss on ignition and Kjeldahl digestion for estimating organic carbon and total nitrogen in estuarine marsh soils: calibration with dry combustion. Estuaries, 14: 175-179

Del Pilar Ruso Y, De La Ossa Carretero JA, Giménez Casalduero F, et al. 2007. Spatial and temporal changes in infaunal communities inhabiting soft-bottoms affected by brine discharge. Marine Environmental Research, 64: 492-503

Del Vals TA, Conradi M, Garcia-Adiego E, et al. 1998. Analysis of macrobenthic community structure in relation to different environmental sources of contamination in two littoral ecosystems from the Gulf of Cádiz (SW Spain). Hydrobiologia, 385: 59-70

Echavarri-Erasun B, Juanes JA, García-Castrillo G, et al. 2007. Medium-term responses of rocky bottoms to sewage discharges from a deepwater outfall in the NE Atlantic. Marine Pollution Bulletin, 54: 941-954

Elmanama AA, Afifi S, Bahr S. 2006. Seasonal and spatial variation in the monitoring parameters of Gaza Beach during 2002–2003. Environmental Research, 101: 25-33

García-Raso JE, Manjón-Cabeza ME. 2002. An infralittoral decapod crustacean community of southern Spain affected by anthropogenic disturbances. Journal of Crustacean Biology, 22: 83-90

Guerra-García JM, García-Gómez JC. 2004. Crustacean assemblages and sediment pollution in an exceptional case study: A harbour with two opposing entrances. Crustaceana, 77(3): 353-370

Hamouda AZ, Abdel-Salam KM. 2010. Acoustic seabed classification of marine habitats: Studies in the Abu-Qir Bay. Journal of Oceanography Marine Sciences, 1 (1): 11-22

Kocataş A, Ergen Z, Katağan T, et al. 1988. Evolution a long terme (1974-1987) des peuplements benthiques sur substrat meuble du Golfe d' İzmir scumis a des multiples pollutions.- Rapp. Comm. Int. Mer. Medit., 31: 2

Ledoyer M. 1965. Sur Quelques Especes Nouvelles D'Iphinoe (Crustacea Cumacea) Discussion et Description Comparative des Especes Europeennes Deja Connues. Recueil des Travaux de la Station Marine d'Endoume, 39(55): 253-295

Metcalf, Eddy Inc. 2003. Wastewater Engineering: Treatment and Reuse (revised by Tchobanoglous G, Burton FL, Stensel HD), McGraw-Hill, Boston, USA

Morrisey DJ, Turner SJ, Mills GN, et al. 2003. Factors affecting the distribution of benthic macrofauna in estuaries contaminated by urban runoff. Marine Environmental Research, 55: 113-136

Okuş E, Uysal A, Yüksek A, et al. 1996. Biological aspects of the rehabilitation of Golden Horn". İstanbul Water and Sewage Administration. Istanbul University, Institute of Marine Sciences and Management, Vefa, Istanbul (in Turkish)

Rinderhagen M, Ritterhoff, J, Zauke GP. 2000. Crustaceans as bioindicator. In: Biomonitoring of Polluted Water-Reviews on Actual Topics. Trans Tech Publications - Scitech Publications (Gerhardt A, ed). Environmental Research Forum 2000 9, Uetikon-Zuerich, 161-194

Sawyer CN, McCarty PL, Parkin GF. 2003. Chemistry for Environmental Engineering and Science (5$^{th}$ edition). McGraw-Hill, Boston, USA

Shannon CE, Weaver V. 1949. A mathematical theory of communication. 101-117, Princeton University Press Illinois, USA

Soyer J. 1970. Contribution a l'etude des copepodes harpactioides de Mediterranee occidentale”, 2. Tachidiidae Sars, Lang. Vie Milieu, 21 (2-A): 261-278

Terlizzi A, Fraschetti S, Guidetti, P, et al. 2002. The effects of sewage discharge on shallow hard substrate sessile assemblages. Marine Pollution Bulletin, 4: 544-550

Tuğrul İçemer G, Koşun E. 2003. The effects of Sewage on Benthic Community in Antalya Bay, Turkey. The Sixth International Conference on The Mediterranean Coastal Environment (MEDCOAST 03). 753-758, Ravenna, Italy

Turkish Statistical Institute (TSI). 2010. Belediye Atıksu İstatistikleri Veri Tabanı.- data set of municipal wastewater statistics, retrieved from the internet from http://tuikrapor.tuik.gov.tr/reports/rwservlet?cevredb2=&report=CEVAT13.RDF&p_pkod=0&p_yil1=2006&desformat=html&p_dil=1&ENVID=cevredb2Env, 2006. Accessed on April 20 2010

Venturini N, Muniz P, Rodríguez M. 2004. Macrobenthic subtidal communities in relation to sediment pollution: the phylum-level meta-analysis approach in a south-eastern coastal region of South America. Marine Biology, 144: 119-126

Zhang WJ. 2012a. Computational Ecology: Graphs, Networks and Agent-based Modeling. World Scientific, Singapore

Zhang WJ. 2012b. How to construct the statistic network? An association network of herbaceous plants constructed from field sampling. Network Biology, 2(2): 57-68