Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(6): 307-313

Received: 04-09-2017
Accepted: 06-10-2017

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The species list belonging to some benthic invertebrate groups in a coastal lagoon: Kamil Abduş Lagoon (İstanbul, Turkey)

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Abstract
The faunal composition of certain benthic invertebrate groups living in Kamil Abduş Lagoon (Turkey) was analyzed. In this context, the present work aims to explore present-day Kamil Abduş lagoon invertebrate diversity. This study focused on the freshwater, brackish water and marine water sections of the Kamil Abduş lagoon, where salinities with different. This small and shallow lagoon in located in the Tuzla district of Istanbul is hydrologically connected with the Sea of Marmara. Major part of this lagoon is strongly influenced from marine water input. At the same time, lagoon is also impacted by anthropogenic activities. A total of 63 species and 93 benthic invertebrate genera were found. According to our findings, Kamil Abduş lagoon is a shallow, water column is well mixed, brackish, well oxygenated, alkaline and meso- to eutrophic lagoon.

Keywords: Coastal lagoon, brackish water, benthic, invertebrate species, taxonomic list, urbanization

Introduction

Lagoons are feature productive aquatic communities and play an important ecological role in ecosystems, providing food and shelter to many important organisms, stabilizing sediments, and regulating. Due to abundance of nutrient and food, naturally, majority of benthic organisms have been found in the coastal section of the estuary, lagoons, gulfs, bays and coves. Lagoons are ecologically valuable habitats for numerous benthic organisms. Benthic organisms are considered important main elements of an ecosystem, therefore, analyse studies performed on the benthic communities can be presented very important knowledge to biomonitoring studies. The existence of certain benthic organism can be important indicators of environmental quality assessments for lagoons, since some taxon are both sensitive and tolerant of environmental alterations. Therefore, benthic organisms can be used as tools to verify possible changes in a lagoon. A great number of mobile or sessile aquatic organisms live in or on the substrate of the benthic zone of lagoons. Some benthic organism can grow and live attached to solid substrates, on rocks, on the sediment or on macrovegetation. According to Garrido *et al.* [1], the water salinity, surface area, width and length of the main water body section of lagoon, existence of outlet and inlet water channels can be considered as key factor limiting and defining the environmental niche space of benthic macroinvertebrates in lagoonal ecosystems.

The geomorphology around of Kamil Abduş lagoon area has changed dramatically within last forty year with increased anthropogenic impact [2]. In the present day, surrounding of the lagoon is covered with human settlements and shipyards.

Taxonomic [3], ecological (Orhon & Kıratlı 1992 [4, 5, 6], and both geological and ecological [2] studies have been performed on Kamil Abduş Lagoon, while numerous taxonomical and ecological studies have been conducted for the determination of single or several benthic invertebrate groups in the lagoons of Turkey. However, the list of some living benthic invertebrate species in the Turkey lagoons had been given [7, 8, 9].

The main objective of this study is presented of the species list of some benthic invertebrate groups found in the Kamil Abduş (Balık) Lagoon of İstanbul (Turkey).

2. Material and methods

2.1 Study site

Kamil Abduş Lagoon (40°49’47.20”N-29°17’12.80” E) is a small (75 ha) coastal lagoon that hydrologically connected to the Sea of Marmara, (see Figures 1). The depth of this shallow coastal lagoon generally varies between 30 and 80 cm, with a maximum of 1.3 m. The coastal barrier is connected to the sea by artificial two inlets, which are always open. The geomorphology around of Kamil Abduş lagoon area has changed dramatically within last forty year due to increased anthropogenic impacts [2]. For, shorelines of the Kamil Abduş lagoon are surrounded with a mega city such as İstanbul. So, the area is thus presently impacted by urbanization.

2.2. Sampling and Laboratory Techniques

For identification of the benthic species, samples collected from four sampling sites over a one-year period using hand nets (mesh size of 50 µm) from February 2016 to January 2017. Samples were collected from a one-square-meter (1 m^2) surface area at each a sampling site.

At each sampling site, the collected benthic material was fixed with 70% ethyl alcohol in polyethylene jars in situ, and carried to the laboratory in the jars. The samples were brought to the laboratory, where the sediment was washed with pressurized tap water and separated into five grain-size fractions using standardized sieves (mesh sizes of 2.0, 1.5, 0.5, 0.25, and 0.125 mm). The sieved samples were preserved in 70% ethyl alcohol solution. Benthic specimens were isolated from material, and then, species identifications were performed with the using a stereomicroscope.

In the laboratory, water samples (0.5–1.0 L) were filtered using glass microfiber filters (0.45 µm 45/90 mm Ø) for the determination of dissolved nutrients (nitrite, NO_2^-; nitrate, NO_3^-; and orthophosphate, PO_4^{3-}) according to the methods outlined by the APHA [10] and Grasshoff *et al*. [11]. For chlorophyll a (Chl-a) determination, water samples (according to phytoplanktonic density 0.5 L or 1.0 L) were filtered through Whatman GF/C glass microfiber filters. Pigments were extracted in the laboratory with 90% acetone and measured following Vollenweider [12] method. Spectrophotometric measurements were performed using a Shimadzu UV-1800 spectrophotometer.

Seven other physicochemical variables commonly used in studies of fresh and brackish water habitats were measured between February 2016 and January 2017. The standard hydrogen electrode (SHE, Mv]), pH, percentage of oxygen saturation (Sat, %), dissolved oxygen (DO, mg l^{-1}), electrical conductivity (EC, µS/cm), salinity (Sal, psu), and water temperature (Tw, °C) were measured in situ using electronic probes (WTW 340i multimeter) at each of the four sampling sites in the lagoon.

Fig 1: Kamil Abduş lagoon (northern coast of the Sea of Marmara, Turkey): location of the sampling sites (red dots are sampling sites)

The coordinates for each sampling site were determined using a handheld Global Positioning System (GPS) receiver. GPS device coordinates and other identifiable characteristics of each sampling site are given in Table 1. Macrophyte species were identified for each sampling sites showed in Table 1.

Table 1: Coordinates and other characteristics of each sampling site.

Sampling sites	Coordinates	Depth (cm)	Substrate	Flora
1	40°49'50.69"N 29°16'43.35"E	50	Sandy-partly rocky	*Cystoseira barbata* (Stackhouse) C. Agardh 1820 *Gracilaria gracilis* (Stackhouse) Steentoft, L Irvine & Farnham 1995 *Ulva rigida* C.Agardh 1823 *Ulva intestinalis* L. 1753 *Ulva lactuca* L. 1753 *Cymodocea nodosa* (Ucria) Ascherson 1870 *Ceramium virgatum* Roth 1797 *Codium tomentosum* Stackhouse 1797
2	40°49'58.09"N 29°17'03.18"E	50	Sandy mud- partly rocky	*Cystoseira barbata* (Stackhouse) C. Agardh 1820 *Gracilaria gracilis* (Stackhouse) Steentoft, L Irvine & Farnham 1995 *Ulva intestinalis* L. 1753 *Cymodocea nodosa*(Ucria) Ascherson 1870
3	40°49'58.66«N 29°17'32.45"E	50	Sandy mud	*Ulva intestinalis* L. 1753 *Phragmites australis* (Cav.) Trin. ex Steud.
4	40°50'10.57"N 29°17'28.46"E	30	Muddy sand	*Phragmites australis* (Cav.) Trin. ex Steud. *Juncus maritimus* Lam., *Holoschoenus maritimus* (L.) Palla., Filamentous algae

For the identification of species the following references are used: for Foraminifera Cimerman & Langer [13], Loeblich & Tappan [14, 15]; for Cnidaria; Hayward &Ryland [16] and Manuel [17]; for Polychaeta Campoy [18], Day [19] and Fauvel [20, 21]; for Arthropoda Zariquiey Alvarez [22], Riedl [23], Holthuis [24], Kırkım [25], Kocataş [26]) and Galil *et al*. [27]; for Mollusca Locard [28], Tebble [29], Parenzan [30, 31, 32], Nordsieck [33], Gaillard [34], Poutiers [35], Poppe & Goto [36], Stock [37], and Zenetos *et al*. [38]; for Bryozoa Bock & Gordon [39, 40]; for Echinodermata Koehler [41] and Tortonese [42]. The ERMS [43] and the ITIS [44] databases were used for the classification and nomenclature of the defined species.

2.3 Statistical Analysis

Binary (presence–absence) data were used to show the relationships among species by means of Jaccard's coefficient test of unweighted pair group mean averages (UPGMA) analysis provided by the MultiVariate Statistical Package (MVSP) program version 3.22 [45]. Jaccard's coefficient test was used to display clustering relationships among the 4 sampling sites and the 63 species.

3. Results

The water of Kamil Abduş Lagoon is classified as sodium chloride with alkaline pH (see Table 2). Seasonal thermal fluctuations were recorded at the four sampling sites. The lowest water temperature was measured at sampling site 4 in January 2017 (3.6 ºC), the highest at sampling site 3 during May 2016 (30.6 ºC). All the water examined in the lagoon was found to be well oxygenated. The lowest water salinity was measured at sampling site 4 in February 2016 (0.1 psu), the highest at sampling site 3 during September 2016 (36.2 psu). According to our results, the lagoon can be clearly categorized as a poly-euhaline saline water body, in accordance with the Venice symposium [46]. The lowest water electrical conductivity was measured in the fourth sampling sites of the lagoon in February 2016 (0.72 mS/cm) and highest degree of electrical conductivity in the third sampling site during the April of 2016 (58.4 mS/cm). Present invertebrate species in the Kamil Abduş lagoon were listed in Table 3 using the systematic classification of proposed by WoRMS [43] and ITIS [44].

Table 2: Mean values and standard deviations of measured physicochemical parameters (mean values ± standard deviations). Abbreviations: Tw (water temperature, °C), Sal. (Salinity, psu), EC (electrical conductivity, mS/cm), ORP (oxidation-reduction potential, mV), DO (dissolved oxygen mg l^{-1}), Sat. % (saturation), ATP (Atmospheric pressure, mbar), Chl-a (chlorophyll a µg l^{-1}), Nitrite ($N–NO_2^-$ mg l^{-1}), Nitrate ($N–NO_3^-$ mg l^{-1}), and OP (orthophosphate, PO_4^{3-} mg l^{-1})

	Tw	pH	ORP	DO	Sat.	Sal.	EC	Chl-a	Nitrite	Nitrate	OP
ST.1											
Min.	7.1	7.82	-83	4.16	50.9	21.5	34.3	0.46	0.002	0.025	0.031
Max.	29.4	8.81	-55	9.5	91.1	24.4	58.4	8.56	0.106	0.833	2.651
Mean ± SD	18.4±7.9	8.28±0.32	-64±48	7.08±1.99	72.5±13.7	23.7±1.0	39.6±6.2	3.19±2.73	0.025±0.032	0.143±0.244	0.270±0.750
ST.2											
Min.	7.4	7.96	-85	3.64	23.4	22.4	36.5	0.64	0.002	0.012	0.035
Max.	29.3	8.83	-62	11.5	103.5	25.2	39.6	8.8	0.232	0.855	2.915
Mean ± SD	18.7±8.4	8.32±0.30	-70±7	6.78±2.35	64.3±21.1	24.0±0.9	38.3±1.2	3.78±2.57	0.035±0.065	0.241±0.307	0.740±1.236
ST.3											
Min.	8.6	7.09	-108	0.93	7.8	4.2	7.74	2.62	0.001	0.007	0.054
Max.	30.6	9.22	-11	12.17	119	25.2	39.3	349.2	2.731	2.481	3.087
Mean ± SD	19.4±8.1	8.29±0.64	-69±30	5.92±3.59	63.3±34.6	18.2±7.0	29.69±10.07	62.59±100.4	0.526±0.996	0.769±0.983	0.704±0.995
ST.4											
Min.	3.8	6.99	-89	4.66	36.1	0.1	0.72	3.66	0.006	0.001	0.04
Max.	30	8.39	-4	11.42	125.7	36.2	55.5	698.1	0.485	3.193	2.076
Mean ± SD	16.8±10.7	7.62±0.43	-31±26	7.48±1.78	79.8±27.0	14.7±13.2	23.43±20.21	84.70±215.8	0.128±0.183	0.710±0.982	0.606±0.870

Table 3: List of currently living benthic invertebrate species of the Kamil Abduş lagoon to date.

Taxon	St.1	ST.2	ST.3	ST.4	Taxon	St.1	ST.2	ST.3	ST.4
Phylum: Foraminifera					Order: Decapoda				
Class: Globothalamea					*Crangon crangon* (Linnaeus, 1758)	+	+	+	
Ammonia beccarii (Linnaeus, 1758)	+	+	+	+	*Carcinus aestuarii* Nardo, 1847	+	+	+	
Ammonia tepida (Cushman, 1926)	+	+	+	+	*Diogenes pugilato*r (Roux, 1829)	+	+	+	
Elphidium depressulum Cushman, 1933	+	+			Class: Insecta				
Haynesina germanica (Ehrenberg, 1840)	+	+			Order: Diptera				
Haynesina depressula (Walker & Jacob, 1798)	+	+			*Chironomus anthracinus* Zetterstedt, 1860			+	+
Class: Tubothalamea					*Chironomus plumosus* (Linnaeus, 1758)			+	+
Spiroloculina angulata Cushman, 1917	+	+			Phylum: Mollusca				
Spiroloculina ornata d'Orbigny, 1839	+	+			Class: Scaphopoda				
Siphonaptera aspera (d'Orbigny, 1826)	+	+			*Antalis vulgaris* (da Costa, 1778)	+	+	+	
Quinqueloculina laevigata d'Orbigny, 1839	+	+			*Dentalium vulgare* (da Costa, 1778)	+	+	+	
Phylum: Cnidaria					Class: Gastropoda				
Class: Scyphozoa					*Bittium latreillii* (Payraudeau, 1826)	+	+	+	
Aurelia aurita (Linnaeus, 1758)	+	+	+		*Bittium reticulatum* (da Costa, 1778)	+	+	+	
Class: Anthozoa					*Ecrobia ventrosa (*Montagu, 1803)	+	+		
Actinia equina (Linnaeus, 1758)	+				*Hydrobia acuta* (Draparnaud, 1805)	+	+	+	
Phylum: Annelida					*Myosotella myosotis* (Draparnaud, 1801)	+	+		
Class: Clitellata					*Nassarius reticulatus* (Linnaeus, 1758)	+	+		
*Limnodrilus hoffmeister*i Claparède, 1862	+	+			*Pusillina radiata* (Philippi, 1836)	+	+		
Class: Polychaeta					*Retusa truncatula* (Bruguière, 1792)	+	+		
Capitella capitata (Fabricius, 1780)	+	+			*Rissoa monodonta* Philippi, 1836	+	+		
Hediste diversicolor (O.F. Müller, 1776)	+	+			Class: Bivalvia				
Janua pagenstecheri (Quatrefages, 1865)	+	+			*Abra alba* (W. Wood, 1802)	+	+	+	
Owenia fusiformis Delle Chiaje, 1844	+	+			*Abra segmentum* (Récluz, 1843)	+	+	+	
Polydora ciliata (Johnston, 1838)	+	+			*Chamelea gallina* (Linnaeus, 1758)	+	+		
Serpula vermicularis Linnaeus, 1767	+	+	+		*Cerastoderma glaucum* (Bruguière, 1789)	+	+	+	
Phylum: Arthropoda					*Flexopecten glaber* (Linnaeus, 1758)	+	+		
Subphylum: Crustacea					*Mytilus galloprovincialis* Lamarck, 1819	+	+	+	
Class: Hexanauplia					*Ostrea edulis* Linnaeus, 1758	+	+		
Perforatus perforatus (Bruguiere 1789)	+	+			*Pholas dactylus* Linnaeus, 1758	+	+		
Class: Malacostraca					*Ruditapes decussatus* (Linnaeus, 1758)	+	+		
Order: Mysida					*Ruditapes philippinarum* (Adams & Reeve, 1850)	+	+		
Diamysis cymodoceae Wittmann & Ariani, 2012	+	+			Phylum: Bryozoa				
Mesopodopsis slabberi (Van Beneden, 1861)	+	+			Class: Gymnolaemata				
Order: Amphipoda					*Cellaria salicornioides* Lamouroux, 1816	+	+		
Caprella equilibra Say, 1818	+	+	+		*Cryptosula pallasiana* (Moll, 1803	+	+		
Corophium orientale Schellenberg, 1928	+	+	+		*Scrupocellaria scruposa* (Linnaeus, 1758)	+	+		
Gammarus aequicauda (Martynov, 1931)	+	+	+	+	Phylum: Echinodermata				
Gammarus crinicornis Stock, 1966	+	+	+		Class: Echinoidea				
Phtisica marina Slabber, 1769	+	+	+		*Echinus melo* Lamarck, 1816	+			
Order: Isopoda					Class: Asteroidea				
Idotea baltica (Pallas, 1772)	+	+	+		*Asterias rubens* Linnaeus, 1758	+			
Sphaeroma serratum (Fabricius, 1787)	+	+	+		*Astropecten irregularis pentacanthus* (Delle Chiaje, 1827)	+			
Order: Tanaidacea					Total number of species per station	61	57	28	5
Leptochelia savignyi (Krøyer, 1842)	+	+	+						
Tanais filiformis Lilljeborg, 1864	+	+	+						
Tanais dulongii (Audouin, 1826)	+	+	+						

The number of species and percentage of the frequency for identified living benthic invertebrates groups at each sampling site are shown in Figure 2.

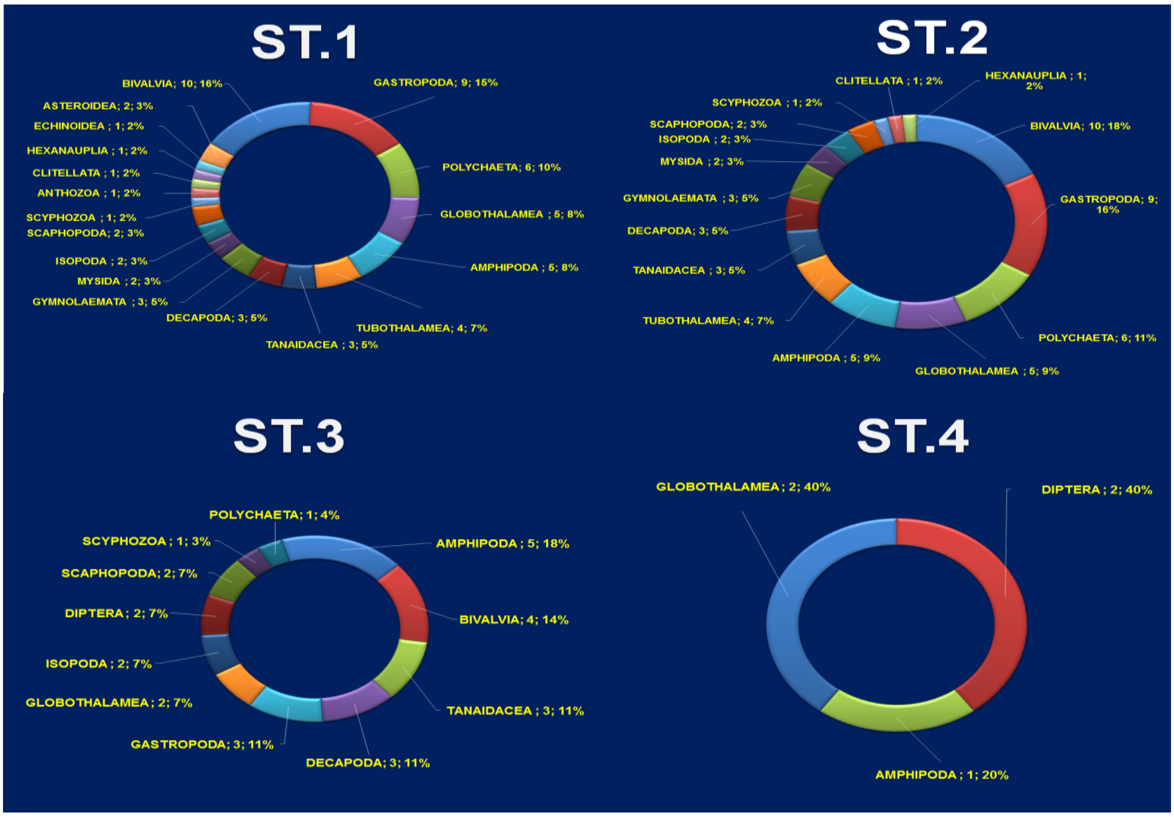

Fig 2: The number of species and percentage of the frequency for identified living benthic invertebrates groups at each sampling site.

Based on species binary (presence/absence) data, Jaccard's coefficient dendrogram shows three main clusters among the four sampling sites (see Figure 3). The first cluster comprised sampling sites 1 and 2, the second cluster sampling site 3, and the third cluster-sampling site 4.

This clustering can be explained in the following way: sampling sites 1 and 2 are clearly under the influence of water from the Sea of Marmara, while seawater continuously flows into the lagoon by via two short and narrow channels. Therefore, sampling sites 1 and 2 features many marine species inhabitants. Both seawater and freshwater enter the surface layers of sampling site 3. Therefore, many marine and typical brackish species were determined there. Sampling site 4 was clearly affected by freshwater, with freshwater and brackish water species observed at this site, and the faunal composition of sampling site 4 was significantly different from those of the other sites.

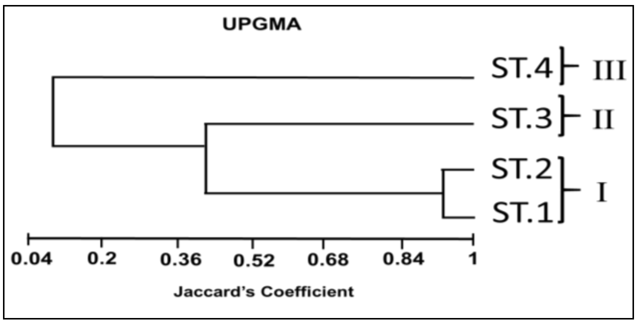

Fig 3: Jaccard's coefficient similarity dendrograms show the faunal similarity among the 4 sampling sites (based on presence/absence of species).

4. Discussion

The presence of 63 species belonging to 40 genera was recorded in this study. The list of identified species in Kamil Abduş lagoon is presented (see Table 3). The species list of Kamil Abduş lagoon is presented (see in Table 3). The results of the present study allowed for the definition of two ecotopes of the Kamil Abduş lagoon based on salinity: freshwater and a brackish water ecotope. The commonest invertebrate groups in sampling site 1 were Bivalvia (Mollusca) present in 10 species (16% of total), Gastropoda (Mollusca) (15 species, 15%), Polychaeta (6 species, 10%). Globothalamea (Foraminifera) (5 species, 8%), and Amphipoda (5 species, 8%) (See figure 2). This faunal composition could only be explained by the influence of sea waters. The commonest invertebrate groups in sampling site 2 were Bivalvia (Mollusca) present in 10 species (18% of total), Gastropoda (Mollusca) (9 species, 16%), Polychaeta (6 species, 11%). Globothalamea (Foraminifera) (5 species, 9%), and Amphipoda (5 species, 9%) (See figure 2). This situation could be explained by the influence of sea waters. All of these taxa recorded in sampling site 1 and 2 may tolerate to brackish water and marine water conditions. The commonest invertebrate groups in sampling site 3 were Amphipoda present in 5 species (18% of total), Bivalvia present in 4 species (14% of total), Tanaidacea (3 species, 11%), Decapoda (3 species, 11%) and Gastropoda (3 species, 11%), (See figure 2). All of these recorded taxa in sampling site 3 may tolerate to brackish water conditions.

Abundance of the larvae of Diptera (Chironomidae) at sampling site 4 show low species richness and exist of stagnant waters. This situation could be explained by input of freshwater. Sampling sites 1 and 2 had been colonized by both marine species (allochthon) and brackish water species (autochthon).

The results suggest that benthic communities of this coastal lagoon can be highly impacted from input of marine waters. Therefore, their benthic communities are similar.

The present study indicates that input of marine water is effect of the structure of benthic communities and spatial distribution of specific taxa in both sampling sites 1 and 2.

Their benthic communities are similar. But limited freshwater (generally rainy water) inputs influence the structure of benthic communities and spatial distribution both at sampling sites 3 and 4. Therefore, their benthic communities of this sampling sites are dissimilar than sampling sites 1 and 2.

Some species with marine affinities were generally more abundant had been found in first and second sampling sites. The species with brackish water affinities species more abundant found in the third sampling site. The species with freshwater / brackish water affinities were found abundant in the fourth sampling site. All results indicate that all species were identified from those habitats appropriate to their ecological and biological preferences.

Tuzla is one of the most industrialized areas of Istanbul, and as three sides of Kamil Abduş Lagoon are surrounded by this fast-growing megacity, it is thus under anthropogenic threat. Local authorities need to be highly diligent to ensure the protection of this fragile ecosystem and wetland.

Mainly, the lagoon is fed by seawater through the two artificial canals. Also, lagoon waters flow to sea through these same canals. The origin of its brackish water is related both to micro-seawater currents and continental freshwater (especially though rainwater) inputs.

The present study indicates that freshwater input influences the structure of benthic communities and spatial distribution of specific taxa.

Physicochemical analyses of Kamil Abduş Lagoon's waters indicate that the physicochemical structure of the lagoon is highly affected by the seawater flowing into the lagoon.

The freshwaters that reaches from the greenhouse irrigation system and rains can be reasons of lower species diversity observed at sampling site 4 than sampling site 1 and 2. The reason of low species diversity at sampling site 3 can be freshwater inputs and especially this situation can be caused from strong salinity fluctuations that linked to floodings and drought.

The Marmara Sea basin occupy by two distinctly different water masses throughout the year [47]: brackish waters (22-26 psu salinity) of Black Sea origin fonning a relatively thin surface layer 0-15 m thick) with a mean residence time of about 4-5 months, separated from the subhalocline waters of Mediterranean origin (38.5-38.6 psu salinity) by a sharp interface (pycnocline) about 10-20 m thick [48, 49]. The basin of Sea of Marmara acts as a receiving water not only for pollutants from the adjacent seas but also for land based chemical pollutants of various origins [47].

The Sea of Marmara has been indicated as a very high polluted sea due to exist of several industrial complexes, discharge of wastewaters, agricultural chemicals, oil pollution and anthropogenic impact [50]. In general, in stable and unpolluted environments, species diversity is high, conversely, diversity is usually low in stressed or polluted environments [51, 52].

In spite of many anthropogenic threats, we observed high species richness in this poly-euhaline coastal lagoon. Therefore, this study may thus also constitute a basis for future investigations aimed at identifying human-induced pollution in marine and transitional marine environments. The increasing of anthropic impacts on this lagoon can be affect the benthic fauna at long term. Therefore, biomonitoring investigations Therefore, biomonitoring investigations must frequently performed for a conservation of lagoon.

Many of the species found on the Kamil Abduş lagoon are recorded in the Sea of Marmara. The Kamil Abduş lagoon is almost continuation of the Sea of Marmara with its faunal structure.

In conclusion, this study performed on the taxonomic diversity and structure of benthic macroinvertebrates in Kamil Abduş lagoon, and it has contributed to identify 63 taxa of benthic invertebrates dominated by Molluscs, Annelida and Crustaceans.

5. Acknowledgement

We would like to express my heartfelt thanks to Prof. Dr. Hüsamettin Balkıs (University of İstanbul, Faculty of Science, Department of Biology) for his support for identification of taxonomic position of some species.

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