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ABUNDANCE AND DIVERSITY OF ZOOPLANKTON IN THE KÖPRÜÇAY ESTUARY, TURKEY

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Abstract:

The physicochemical features and species composition and density of zooplankton of Köprüçay estuary investigated monthly sampling from selected 5 stations between January and December, 2009. In this study, Zooplankton which are Rotifera (20), Cladocera (6), Copepoda (34), and Cnidaria, Tubilariidae, Foraminifera, Tintinida, Cirripedia, Gastropoda, Polychaeta, Chaetognatha, Decapoda, Ichthyoplankton one of each of determined 70 taxons in Köprüçay River estuarin zone. The dominant taxa in Köprüçay River estuarin zone consist of *Oithona nana, Clausocalanus arcuicornis, Acartia discaudata, Paracalanus parvus, Euchlanis dilatata and Cephalodella gibba* and these species are eurohalin character types of zooplankton. In Köprüçay River estuarin zone, the highest and the lowest Copepoda density semptember (25627.33 ±8369 ind./m^3) and february (3050 ±1701 ind./m^3), ; the highest and the lowest Rotifera density january (12152 ±6835 ind./m$^{3)}$ and september (187 ±76 ind./m^3); the highest and the lowest Cladocera density august (2687 ±604 ind./m^3) and february (0 ±0 ind./m^3); the highest and the lowest other organisms february (3226,33 ±586 ind./m^3) and may (648 ±178 ind./m^3), respectively. This article was prepared from the doctoral thesis.

Keywords:

Köprüçay River, Estuary, Zooplankton

Introduction

Estuary is a semi-enclosed coastal body of water, which has a free connection with the open sea, and within sea water is water measurably diluted with freshwater derived from land drainage. Estuaries are where 'fresh' river water and saline sea water mix (Prandle, 2009). The estuarine environment is characterized by having a constantly changing mixture of salt and freshwater, and by being dominated by fine sedimentary material carried into the estuary from the sea and rivers, which accumulates in the estuary to form mudflats. The mixtures of salt and freshwater present challenges to the physiology of the animals, which few are able to adapt to (McLusky and Elliott, 2004).

Estuaries are transition zones between rivers and the sea, which differ from both in abiotic and biotic conditions. Temperature, salinity, and turbidity fluctuation a daily basis and reach more extremes in estuarine waters than they do at sea or in rivers. From a biotic point of view, estuaries are highly productive ecosystems ranking at the same level as coral reefs and mangrove swamps (McLusky and Elliott, 2004).

Salinity and temperature are the most important factors that affect the distribution of estuarine marine organisms because these factors are related to the regulation of metabolism and osmosis (Kinne 1967). The zooplankton of Köprüçay estuarine zone were firstly investigated by this study.

Materials and Methods

Köprüçay River is located south of the Turkey. It extends for 150 km and east near the town of Serik into the Mediterranean Sea with a wide estuary zone (Figure 1). The Köprüçay estuary is classified as a medium sized estuary (Küçük, 1997). The estuary is navigable for approximately 1 km and the widest portion is about 170 m. The system is mostly shallow, mainly between 1.5 and 3 m. Agricultural land within the catchment area are, however, relatively undisturbed.

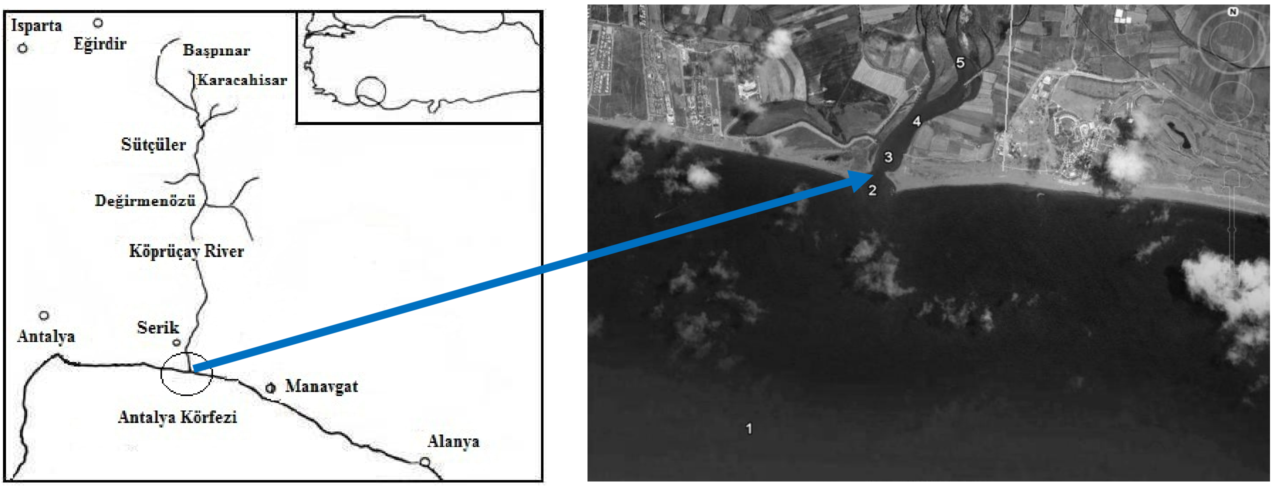


Figure1. Positions of stations and map of the Köprüçay estuary

Physico-chemical (salinity and temperature, pH, dissolved oxygen) properties, biological variables (chlorophyll-a), the zooplankton community structure and biomass were investigated monthly at five stations in the Köprüçay estuary for a period of one year. Four stations were located in the upper, middle and lower reaches of the estuary and one station were located coastal zone to assess spatial patterns in the biology (Figure 1). Temperature, pH, salinity, dissolved oxygen, electrical conductivity at 2, 3, 4 and 5th station were measured separately in the surface and bottom (1.5-2 m depth) but Chl *a* was only measured from the surface. Physico-chemical variables of 1st station were measured separately from surface, 20 and 30 m.

Monthly sampling of zooplankton was performed from January 2009 to December 2009 for 12 months, , using a conical standard plankton net of 55 µm mesh size, with an opening diameter of 17 cm and 1 m length. The net was towed horizontally just beneath the surface for 10 min (speed of boat 1.5 knots) and vertically from the bottom toward the surface (samples were taken from 10, 20 and 30 m for the 1st station and 1.5-2 m depth for 2, 3, 4 and 5th station) A flowmeter was fitted onto the opening of the net to calculate the filtration rate and efficiency. Samples were preserved immediately with buffered formaldehyde solution to make the final concentration of about 4%. In the laboratory, zooplankton species were identified and taxon abundance (per cubic metre) was estimated from a 1 ml subsample, taken after thorough mixing of the entire sample (100 mL) (Özel, 1992). Numerous publications and taxonomic references were used for identification, such as (Edmondson, 1959-a; Elster and Ohle, 1974; Pontin, 1978; Koste, 1978-a, b, Rutner-Kolisko, 1974). Edmondson (1959-b), Rose (1933), Brodskii (1950), Grice (1962), Kasturırangan (1963), Frost and Fleminger (1968), Edmondson (1959-c), Bayly (1972), Newel and Newel (1977), Mazzocchi et al., (1995), Einsle (1996), Palomares et al., (1998), Boltovskoy (1999-a,b), Dussart and Defaye (2001), Boxshall and Halsey (2004-a,b), Boltovskoy, (1999-a,b), Perry (2003).

To determine the chlorophyll *a* (chl. *a*; g l^{-1}) concentration, 100-ml aliquots were filtered through 0.45 μm cellulose acetate filters (Millipore), which were stored frozen until analysis (within 2 or 3 days). Chl. *a* concentration was determined spectrophotometrically using the monochromatic method of Wetzel & Likens (2000).

Results are reported as mean values ± standard errors. One-way ANOVA was used to test for significant effects of location and season on the abundance of total zooplankton, rotifers, cladocerans and copepods. Significant differences were identified at $P<0.05$. The analyses were done using IBM_ SPSS_ 15 for Windows (IBM Company, NY, USA) (Esteves, 2011).

Results and Discussion

Average values and standard errors of the measurements are given the following tables (Table1 and 2). The variances between stations were significantly different ($p<0.05$).

The highest temperature of the surface water was found to be 30.5°C (August 1st station) and the lowest 11°C (January, 5th station); the highest temperature of deep water was recorded 31°C (August 2 and 3rd stations) and the lowest was 11.2°C (January, 5th station) (Figure 2). The difference between surface and bottom water was not significant ($P>0.05$).

The difference between surface and bottom water in June, July, August and September were significant ($P<0.05$) but there were no significant diffferecences were found in other months. The salinity variances that were measured from surface and bottom with highest and lowest values were found to be 36 ppt (August, 1st station), 0.1 ppt (5th station) and 35.9 ppt (August, 1st station 20 and 30 m), 0.1 ppt (December, 5th station), respectively ($P>0.05$) (Figure 3).

The concentration of dissolved oxygen variances that were measured from surface and bottom with highest and lowest values were found to be 10.23 mg/L (February, 5th station),7.4 mg/L (October, 1st station), and 9.8 mg/L (February, 5th station), 7.2 mg/L (October, 1st station 30 m) respectively (Figure 4). The difference between surface and bottom water in June and August were significant ($P<0.05$) but there were no significant differecences were found not significant in other months.

The samples collected during the study period indicate the presence Rotifera (20), Cladocera (6), Copepoda (34), and Cnidaria, Tubilariidae, Foraminifera, Tintinida, Cirripedia, Gastropoda, Polychaeta, Chaetognatha, Decapoda, Ichthyoplankton *one* of each of determined 70 taxons in

Köprüçay River estuarin zone. The zooplankton species studied in the lake are as follow;

ROTİFERA
Trichotria pocillum (Müller, 1773)
Macrochaetus collinsi (Gosse, 1867)
Colurella unicinata (Müller, 1773)
Colurella sp. (Müler, 1773)
Lepadella ovalis (Müler, 1786)
Brachionus plicatilis (Müler, 1786)
Keratella cochlearis (Gosse, 1851)
Lecane luna (Müler, 1776)
Lecane lunaris (Ehr., 1832)
Lecane filexilis (Gosse, 1886)
Monommata longiseta (Müler, 1786)
Cephalodella gibba (Ehr., 1838)
Trichocerca longiseta (Schrank, 1802)
Ascomorpha ovalis (Carlin, 1943)
Gastropus stylifer (Imhof, 1891)
Rotaria sp.
Synchaeta sp.
CLADOCERA
Alona sp.
Bosmina longirostris (O. F. Müller, 1785)
Penilia avirostris (Dana, 1849)
Evadne spinifera P.E.Muller, 1867
Evadne nordmanni (Lovén, 1836)
Podon polyphemoides Leuckart,1859
COPEPODA
Clausocalanus arcuicornis (Dana, 1849)
Clausocalanus furcatus (Brady, 1883)
Pseudodiaptomus marinus Sato, 1913
Acartia discaudata (Giesbrecht, 1892)
Acartia clausi (Giesbrecht, 1889)
Acartia latisetosa (Giesbrecht, 1892)
Acartia negligens (Dana, 1849)
Acartia grani (Sars, 1904)
Paracalanus parvus (Claus, 1863)
Paracalanus aculeatus (Giesbrecht,1888)
Paracalanus nanus (Sars, 1907)
Calocalanus styliremis (Giesbrecht,1888)
Acrocalanus sp.
Temora stylifera (Dana, 1849)
Candacia armata (Boeck, 1872)
Labidocera sp.
Pontella mediterranea (Claus, 1863)
Pleuromamma gracilis (Claus, 1863)
Mecynocera clausi (Thompson, 1888)
Centropages furcatus (Dana, 1852)
Centropages kroyeri (Giesbrecht,1892)
Centropages violaceus (Claus, 1863)
Phaenna spinifera (Claus, 1863)
Oithona nana (Giesbrecht, 1892)
Oithona plumifera (Baird, 1843)
Oithona helgolandica (Claus, 1863)
Cyclops abyssorum (Sars, 1863)
Coryceaus sp.
Oncaea mediterranea (Claus, 1863)
Oncaea minuta (Giesbrecht, 1892)
Sapphirina sp.
Euterpina acutifrons (Dana, 1852)
Microsetella rosea (Dana, 1848)
Macrosetella gracilis (Dana, 1847)
OTHER
Cnidaria (Actinula larvası)
Foraminifera
Tintinida
Cirripedia
Bivalvia
Polychaeta
Ostracoda
Chaetognatha
Decapoda (Zoea)

Table 1. Mean values of hydrological parameters measured on the surface

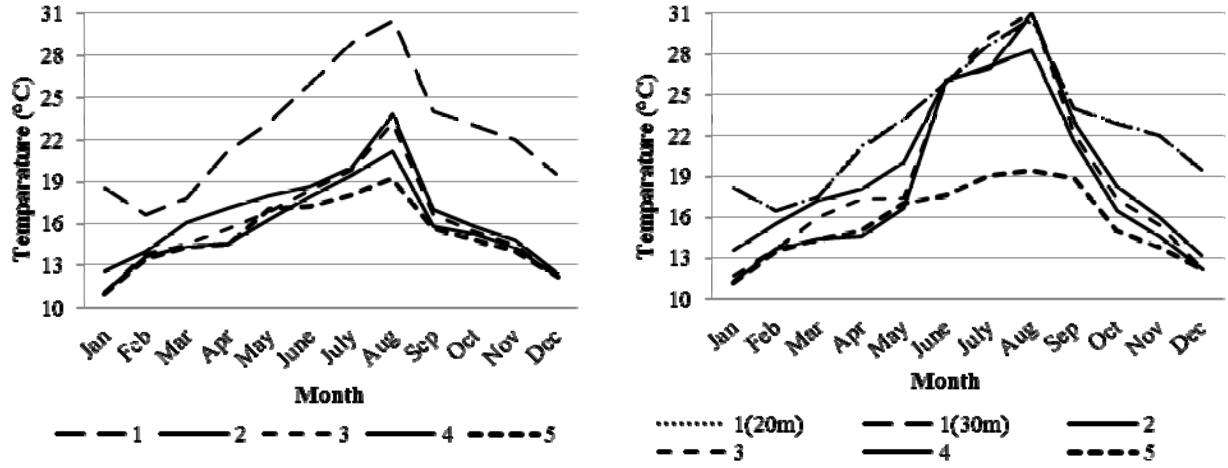
	Stations				
	1	2	3	4	5
Parameter	M±S.E Min-Max	M±S.E Min-Max	M±S.E Min-Max	M±S.E Min-Max	M±S.E Min-Max
Tempature (°C)	22.63 ±1.26^{a} 16.6-30.5	16.69 ±0.92^{b} 12.5-23.8	15.97 ±0.95^{b} 11.1-23.2	15.4 ±0.83^{b} 11.1-21.2	15.10 ±0.69^{b} 11-19.2
pH	8.12-8.48 8.32 ±0.03^{a}	8.05-8.58 8.34 ±0.06^{a}	8.05-8.6 8.34 ±0.05^{a}	8.18-8.7 8.37 ±0.06^{a}	8.11-8.7 8.37 ±0.05^{a}
DO (mg/L)	7.96 ±0.08^{c} 7.4-8.5	8.26 ±0.05^{bc} 7.95-8.6	8.59 ±0.08^{b} 8.15-9.1	9.19 ±0.13^{a} 8.22-9.75	9.57 ±0.16^{a} 8.26-10.23
Salinity (ppt)	35.45 ±0.10^{a} 34.6-36	4.65 ±2.50^{b} 0.2-29.4	0.46±0.13^{b} 0.1-1.8	0.36 ±0.08^{b} 0.1-1.1	0.26 ±0.05^{b} 0.1-0.8
EC (µS/cm)	50600.00 ±866^{a} 46800-57200	5815.71 ±866^{b} 290.6-32600	587.67 ±147^{bc} 290-1980	665.34 ±179^{bc} 267.9-2190	467.60 ±94^{c} 202-1410
Chl-*a* (mg/m^3)	1.45±0.10^{b} 0.9-2.2	3.26 ±0.38^{a} 1.8-6.3	4.12 ±0.49^{a} 2.4-7.5	3.67 ±0.38^{a} 2.2-6.9	1.22 ±0.10^{b} 0.7-1.9
Secchi-depth (m)	9-16 12.33 ±0.58^{a}	0.9-1.2 1.06 ±0.03^{b}	0.7-1.4 1.14 ±0.05^{b}	0.8-1.2 0.99 ±0.04^{b}	0.6-1 0.85 ±0.03^{b}

Different letters in the same row, shows the differences between the stations (P<0.05). DO: dissolved oxygen, EC: electrical conductivity, Chl a: Chlorophyll-*a. M: Mean, S.E: Standart error.*

Table 2. Results of hydrological parameters measured on the bottom stations

	1(30m)	2	3	4	5
Parameter	M±S.E Min-Max	M±S.E Min-Max	M±S.E Min-Max	M±S.E Min-Max	M±S.E Min-Max
Temp. (°C)	22.46 ±1.26^{a} 17.5-30.6	19.87 ±1.64^{ab} 13.1-31	19.05 ±1.85^{ab} 11.7-31	18.07 ±1.75ab 11.4-28.3	15.56 ±0.79^{b} 11.2-19.4
pH	8.31 ±0.02^{a} 8.2-8.51	8.30 ±0.05^{a} 8.05-8.56	8.30 ±0.04^{a} 8.1-8.53	8.35 ±0.06^{a} 8.1-8.7	8.32 ±0.05^{a} 8.08-8.65
DO (mg/L)	7.83 ±0.08^{bc} 7.2-8.41	7.56 ±0.10^{c} 7.12-7.97	7.90 ±0.11^{bc} 7.12-8.32	8.22 ±0.16^{b} 7.13-8.8	8.77 ±0.14^{a} 8.12-9.8
Salinity (ppt)	35.57 ±0.09^{a} 35.3-35.9	24.33 ±4.15^{ab} 2.1-35.5	13.61 ±4.61^{bc} 0.2-35.4	11.58 ±4.82^{bc} 0.2-35.3	8.33 ±4.23^{c} 0.2-33.8
EC (µS/cm)	50991.67 ±896.3^{a} 47000-57100	34485.00 ±6076.53^{ab} 2950-54300	19955.58 ±6822.53^{bc} 301-53000	16772.00 ±6961.53^{bc} 301.2-52600	10950.41 ±5511.66^{c} 278.4-43900

Different letters in the same row, shows the differences between the stations (P<0.05). Temp: temparuture, DO: dissolved oxygen, EC: electrical conductivity, *M: Mean, S.E: Standart error)*



s b

Figure 2. Salinite values (mg/L) measured on the surface (s) and bottom (b) stations

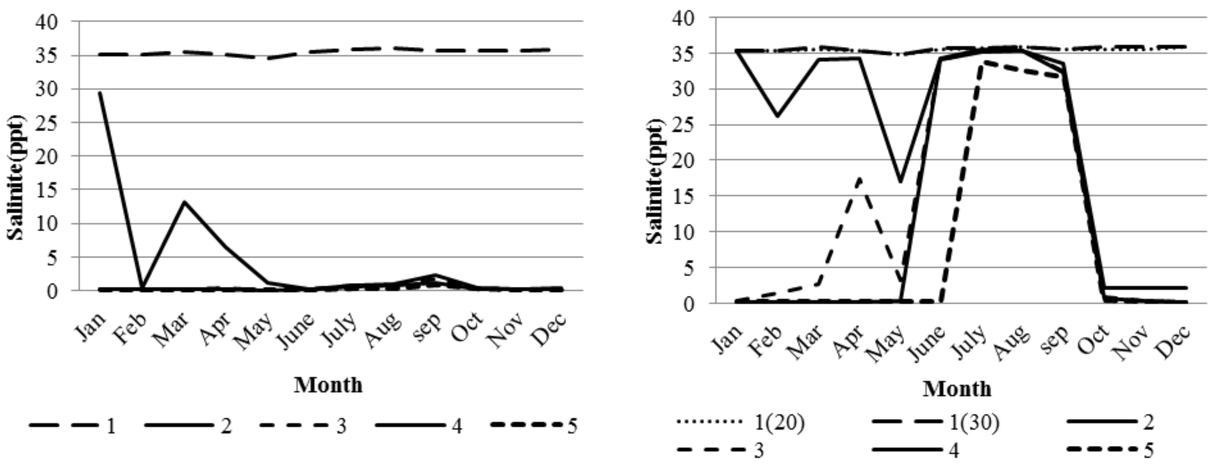


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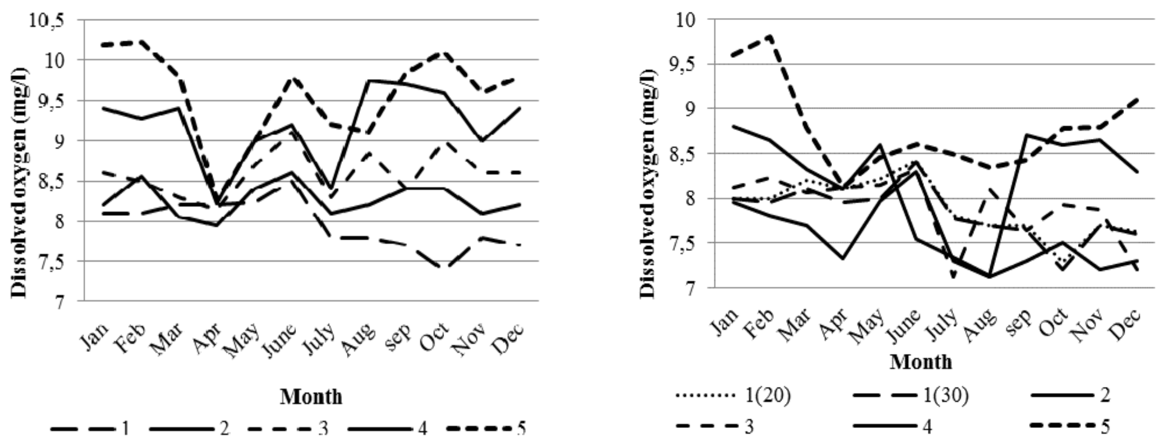
Figure 3. Salinite values (mg/L) measured on the surface (s) and bottom (b) stations



s b

Figure 4. Dissolved oxygen (mg / l) measured on the surface (s) and bottom (b) stations

The densitiy of zooplankton variances with highest and lowest values were found to be copepod September 25627.33 ±8369 ind/m^3, January (2939.33 ±1537 ind/m^3) and Rotifera January 12152 ±6835 ind/m^3, September 187 ±76 ind/m^3, Cladocera August 2687 ±604 ind/m^3, February 0 ±0 ind/m^3, other organisms, March 3226.33 ±586 ind/m^3, May 648.06 ±178 ind/m^3 respectively (Table 3 and Figure 5).

Mean density of zooplankton groups at 2, 3 and 4th stations as a result of horizontal shooting (excluding sea area) figure 6 is also given. Copepod reached the highest density at 3rd station (ind/m3 12519.17 ±3837). The highest mean density of zooplankton was observed at station 3 (21698.33 ±4108 ind/m^3).

Mean density of zooplankton groups at 2, 3 and 4th stations as a result of vertical shooting (excluding sea area) figure 7 is also given. Copepod reached the highest density at 3rd station (ind/m^3 (26025.17 ±6647 ind/m^3). The highest mean density of zooplankton was found at 3rd station (38571.25 ±6532 ind/m^3).

There were no significant differences between depths (10, 20 and 30 meters) at 1st station (P> 0.05). Mean zooplankton density at 1st station is given in figure 8. The highest zooplankton density (15090 ±351 ind/m^3) was obtained in August.

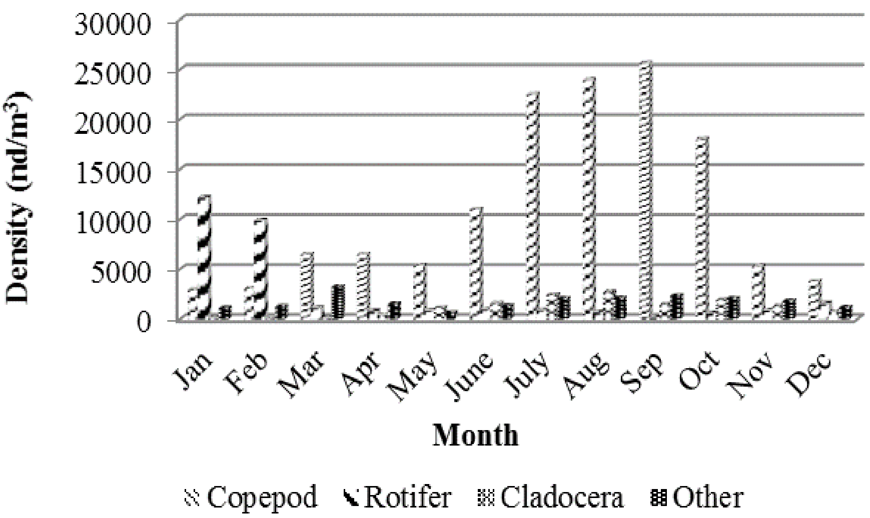


Figure 5. Mean density of zooplankton groups

Table 3. Monthly variation of mean zooplankton in the Köprucay estuary

	Copepod	**Rotifer**	**Cladocera**	**Diğer**
January	2939,33 ±1537^{c}	12152 ±6835^{a}	65 ±43^{d}	1138,39 ±272^{ab}
February	3050 ±1701^{c}	9905 ±6996^{ab}	0 ±0^{d}	1277 ±218^{ab}
March	6482,67 ±1674^{bc}	1139,5 ±475^{abc}	55,33 ±49^{d}	3226,33 ±586^{a}
April	6492,67 ±1945^{bc}	827 ±217^{abc}	351,33 ±137^{cd}	1527,493 ±399^{ab}
May	5397 ±1356^{bc}	866 ±209^{abc}	1172 ±149^{abcd}	648,06 ±178^{b}
June	11004,33 ±4039^{abc}	976 ±259^{abc}	1576 ±97^{abcd}	1340 ±401^{ab}
July	22512 ±7260^{ab}	934 ±263^{abc}	2468,33 ±658^{ab}	2080,33 ±503^{ab}
August	23947 ±8360^{a}	720 ±266^{bc}	2687 ±604^{a}	2115 ±480^{ab}
September	25627,33 ±8369^{a}	187 ±76^{c}	1476,67 ±496^{abcd}	2350,33 ±418^{ab}
October	18017 ±5645^{abc}	626 ±235^{c}	1916,33 ±334^{abc}	2079,33 ±522^{ab}
November	5321,67 ±1639^{bc}	878 ±236^{abc}	1317 ±202^{abcd}	1804,33 ±316^{ab}
December	3803,67 ±1091,501^{c}	905 ±535^{abc}	1467,67 ±281^{bcd}	1838 ±153^{ab}

Different letters in the same row, shows the differences between the months (P<0.05)

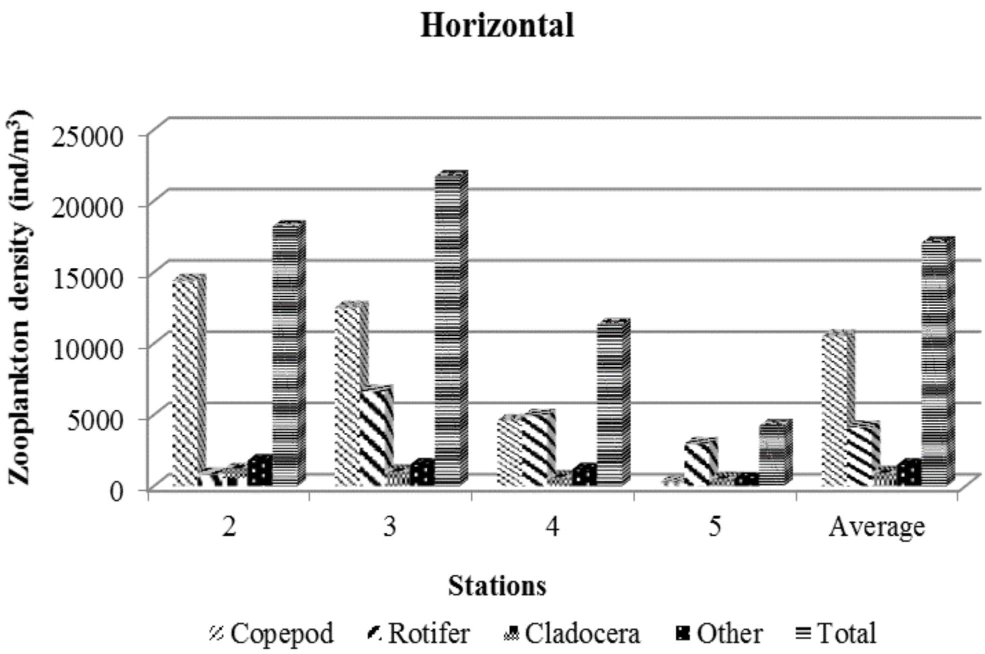


Figure 6. Mean density of zooplankton groups at 2, 3 and 4th stations obtained by horizontal shooting

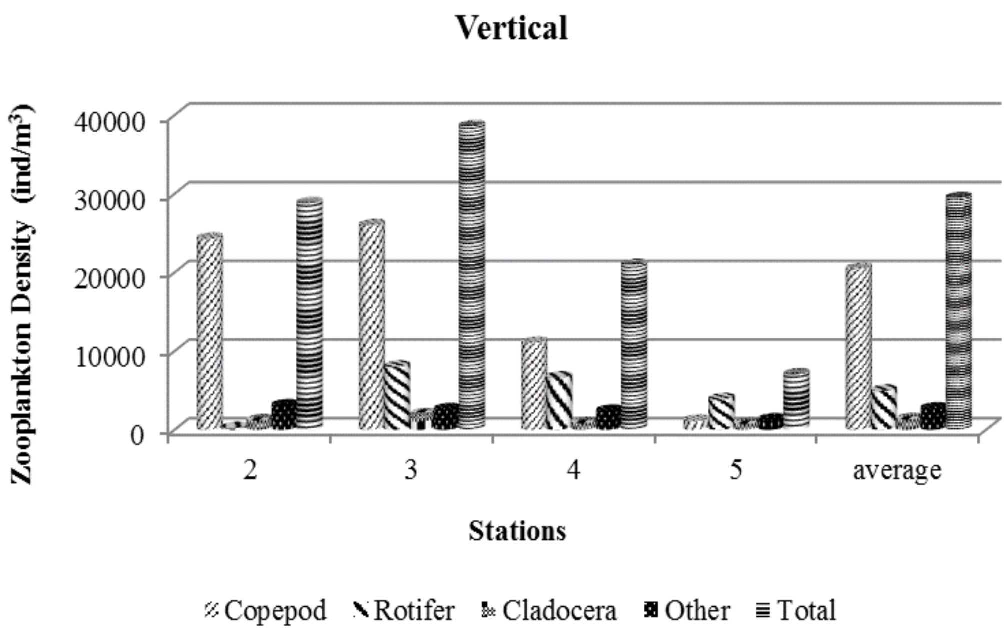


Figure 7. Density of zooplankton groups at 2, 3 and 4th stations obtained by vertical shooting

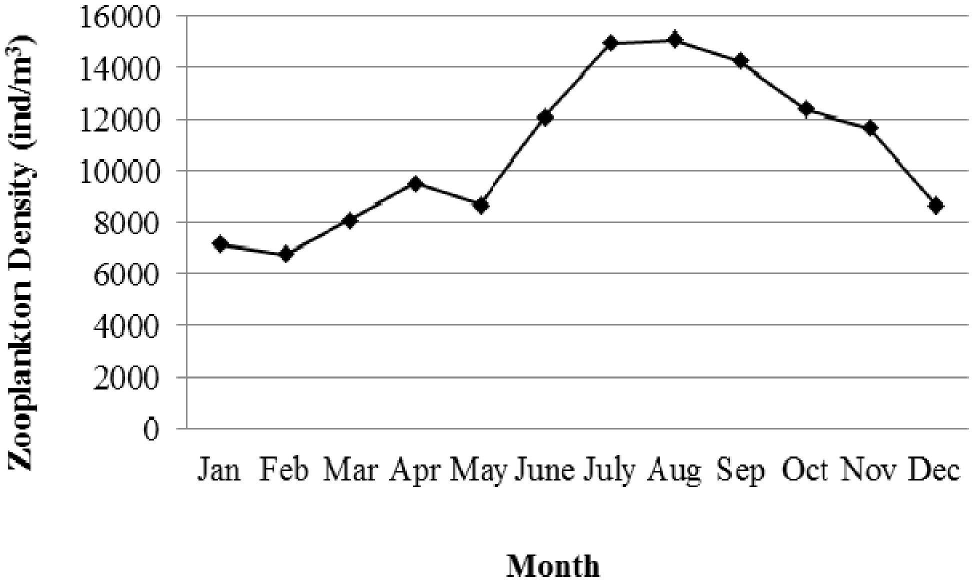


Figure 8. Mean zooplankton density at 1st station (results are shown as mean±standart error)

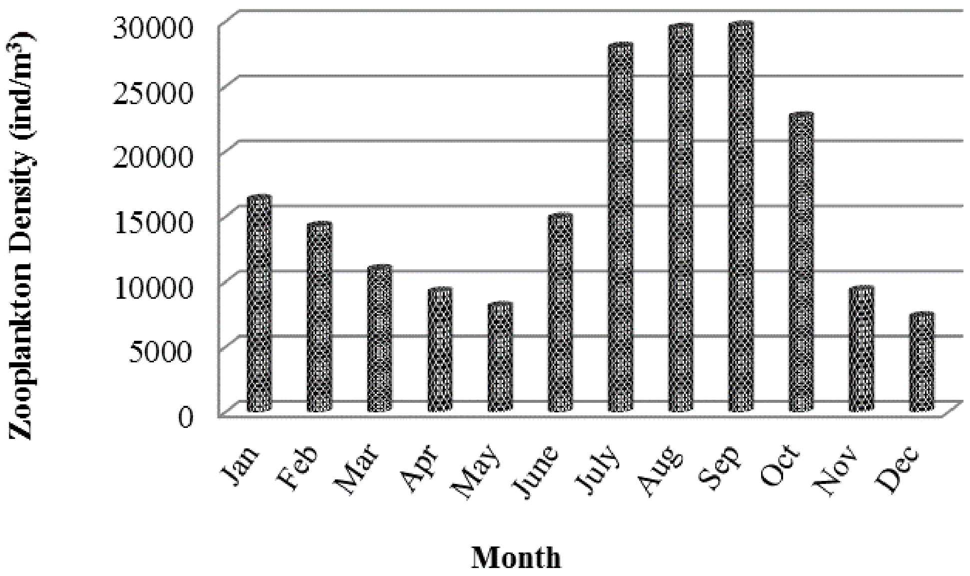


Figure 9. Density of zooplankton density

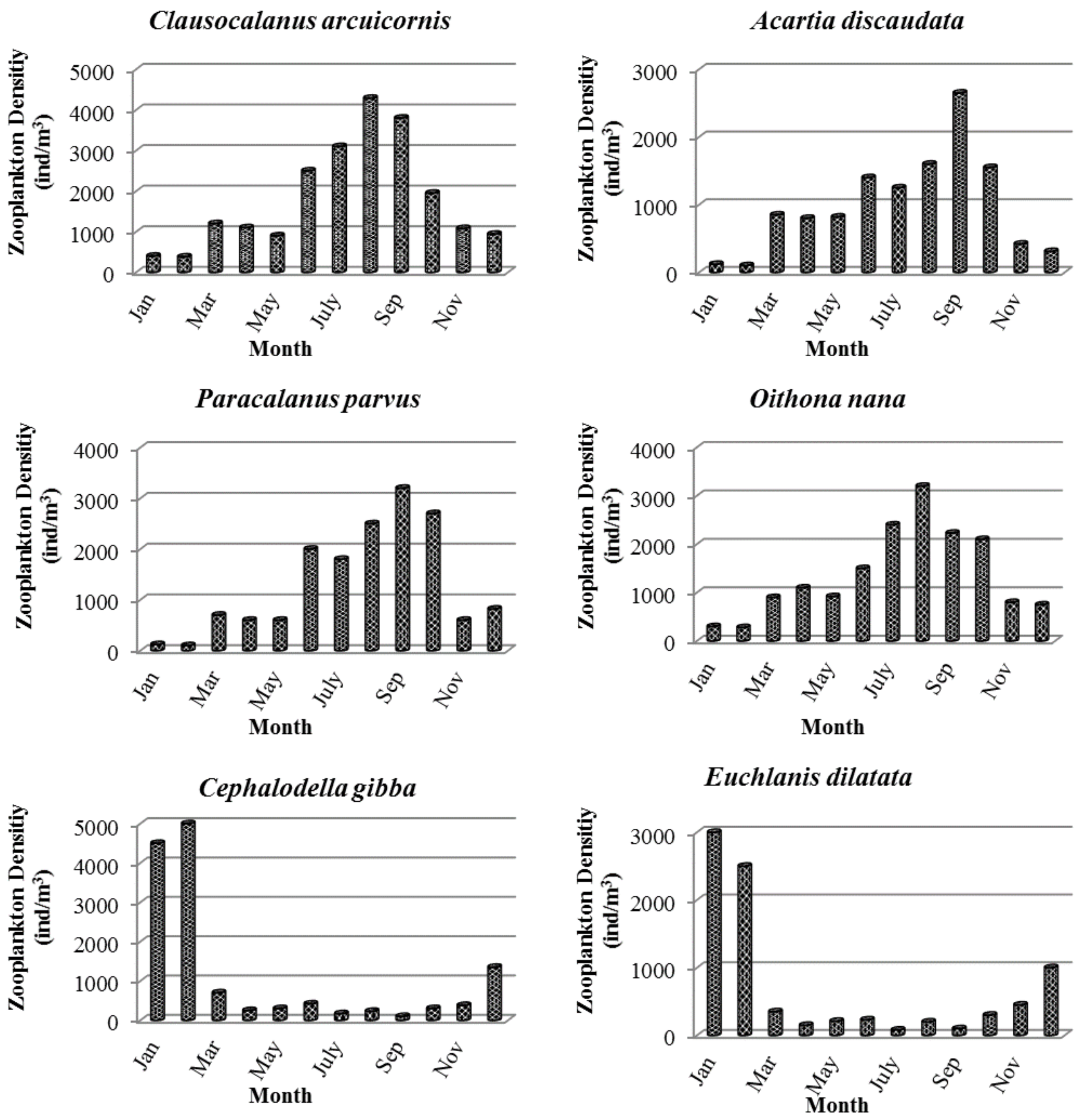


Figure 10. The density of common species as function of months in Köprüçay River estuary

When curve of zooplankton density is observed, two significant increase (peak) has been found (Figure 9). The first and highest was in September and the second and the lower in January. The highest zooplankton density determinated in September (29641.33 ind/m^3), while the lowest density was in March (8083,06 ind/m^3).

The density of common species in accordance with months in Köprüçay River estuary is given in figure 10.

Estuaries are transition zones between rivers and the sea, fresh waters of the river found at the top of the water column due to the differences in density while sea water is moving toward the lower part of the water. Therefore, sampling of plankton in this study in which physico-chemical measurements were performed were made to reflect this situation (bottom and surface).

Temperature values of all stations were found higher at deeper parts than those of the surface waters. The river effect was more dominate during the winter months, while the marine effect continued from April to November. This was seen especially at 2, 3 and 4th stations. By taking into account the mean of temperature values of one year, differences between surface and bottom waters were not statistically significant (P>0,05). Compared to the stations in themselves, 1 and 5 is significantly different from other stations (P<0.05).Similarly, because of the increasing effect of sea during the summer months, salinity has been more than 35 ppt at 2. and 3rd stations. Dissolved oxygen value decreased towards the from sea to the river. The differences between surface and bottom waters in June and August were significant (P<0.05), in other months were not significant (P>0.05). The highest chlorophyll-a value was determined at 3rd station (in May), while the lowest was at 5th station (in December) .It can be concluded as compliance with the conditions of light and temperature during the spring semester, zooplankton grazing during the summer and reduction of light and temperature during winter. Secchi disk is an indicator of the trophic state and a measure of turbidity. Visibility at 3rd station is deeper than 4 and 5thstations. It could be the result of effectiveness of rainfall and river at 4 and 5th stations.

During the sampling preiod 70 *taxa* was observed, thirty-four species of Copepoda was identified (Table 1). Zooplankton community was characterized by the presence of freshwater, estuarine, coastal and oceanic species.

Copepods are clearly dominating in the zooplankton community. Copepods comprised 18-21% of the total zooplankton in January and February. Starting from the spring with the increase of salinity, total copepod was comprised 80, 81 and 86% of community in July, August and September respectively. Among the calanoid families, Paracalanidae, Clausocalanidae and Temoridae were the most important families in terms of abundance, biomass and productivity. (Işinibilir et al., 2008, Miyashita et al, 2009). We found two species of Clausocalanus (*Clausocalanus arcuicornis, C. furcatus*), the calanoid copepod *Clausocalanus arcuicornis* was the most abundant taxon (August, 4290 ind/m^3). *Paracalanus parvus* comprised 10.8 % of zooplankton total abundance in September.

Species belonging to the genus Oithona is typical of the region estuaries (Işinibilir et al., 2008, Vieira et al., 2003, Sterza and Fernandez, 2006,). We found three species of Oithonidae (*Oithona helgolandica, Oithona nana* ve *Oithona plumife*ra), *Oithona nana* and *Oithona plumifera* was seen as dominant taxa at 2 and 3rd stations, but *Oithona helgolandica* were found only at 1st station. O*ithona nana* comprised 10.86% of zooplankton total abundance in Augst.

Among the zooplankton, Pseudodiaptomus and Acartia numerically and by biomass dominate the zooplankton community (Perissinotto et al., 2000; Froneman, 2002a; Kibirige and Perissinotto, 2003b). We found five species of Acartia genus (*Acartia discaudata, Acartia clausi, Acartia latisetosa*, *Acartia negligens* and *Acartia grani*). Especially, *Acartia discaudata* has reached very high number of individuals (September, 2650 ind/m^3). *A.negligens*, on the other hand, is a typically oceanic form and hence ıts absence at the estuarine station is explained (Pillai et al., 1973). *Acartia negligens* were only found at 1st station (marine region).

Six cladocera species (*Alona sp., Bosmina longirostris, Penilia avirostris, Evadne spinifera, E. nordmanni and Podon polyphemoides*) were identified in the Köprüçay estuary. *Evadne spinifera, Podon polyphemoides, Penilia avirostris, Bosmina longirostris* were common species in estuaries (Puelles et al., 2004, Chícharo et al., 2001, Bosh and Taylor, 1968). *Bosmina longirostris, Evadne spinifera, E.nordmanni* ve *Penilia avirostris* at 2, 3 and 4th stations, *Podon polyphemoides* were only determined at 1st station.

Rotifers may also play an important role in the river food web, mainly due to their ability to filter bacteria and small-sized phytoplankton, which are common in this ecosystem. During the period of the investigation, 20 rotifer species were determined. *Notholca squamula, Trichotria pocillum, Euchlanis dilatata, Colurella unicinata, Lepadella ovalis, Cephalodella gibba, Keratella cochlearis* were common species Köprüçay estuary. This species are typically estuaries rotifer species (Azemar et al., 2010, Holst et al., 1998, Crump and Baross, 1996, Kim and Joo, 2000). The density of *Cephalodella gibba* exceeded 5000 ind/m^3 and it accounted for over 50% of the total rotifer community in February.

Conclusion

In conclusion, our results indicate a link between zooplankton distribution and physical features in the area investigated. Zooplankton biomasses were increased with the rise of temperature and salinity. Previous studies have been only focused on lakes, rivers and the sea. There are a few studies on estuarine zooplankton in Turkey (Bat et al., 2007, Işinibilir et al., 2008). This study might contribute to Turkish zooplankton fauna and be a reference for detailed studies in future on Köprüçay estuary zone and other estuaries.

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