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RESEARCH ARTICLE

Temporal changes of copepod abundance and species compositions in the coastal water of Samsun, the southern Black Sea (Turkey)

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Abstract

The copepod fauna in Samsun coastal region of the Black Sea was investigated between January 2008 and December 2008. Species composition and abundance as well as physichochemical factors which may influence on them were determined in the samples monthly collected at five stations in the research area. A Bray-Curtis similarity matrix was created from the copepod abundance data and the analyses of agglomerative hierrarchical cluster analysis and multi-dimensional scaling were performed using similarity matrix. A total of 10 species; including seven species *Calanus euxinus* Hulsemann, 1991*;* *Paracalanus parvus* (Claus 1863); *Centropagaes ponticus* Karavaev, 1894; *Calanipedia aquaedulcis* (Kritchagin, 1873); *Acanthodiaptomus denticornis* (Wierzjski 1857); *Acartia (Acartiura) clausi* Giesbrecht, 1889; *Pseudocalanus elongatus* (Boeck 1965) belonging to Calanoida, one species *Oithona similis* (Claus 1863) belonging to Cyclopoida and two species (*Euterpina acutifrons* Dana, 1852; *Canuella perplexa* T. and A. Scott, 1893) belonging to Harpacticoida were identified in the copepod community. The maximum abundance was observed in December 2008. The minimum abundances were, however, recorded in July and March 2008. Correlation coefficients between the physico-chemical parameters (temperature, Secchi disc, pH, electrical conductivity, TDS (Total dissolved substance), NH_3-N, PO_4, SiO_2) and the abundance of the copepod species were calculated together with the significance levels.

Keywords: Copepoda, Black Sea, biodiversity, hierrarchical cluster analysis, MDS

Introduction

Zooplankton play an important role in studying the faunal biodiversity of aquatic ecosystems. Zooplankton occurrence and distribution influence pelagic fishery potentials. Fish mostly breed in areas where planktonic organisms are plenty so that their young ones can have sufficient food for survival and growth

(Groswami 2004). They are also used as biological indicators for determination of water quality, pollution and eutrophication (Hecky and Kilham 1973; Sharma 1983; Saksena 1987). Zooplankton occurrence, distribution and abundance are of extreme importance in aquatic systems since they are sensitive to disturbances including eutrophication due to antrophogenic impacts such as heavy urbanization, domestic and industrial pollutants and sewage disposal which can alter ecosystem components (Siokou-Frangou *et al*. 1998; Kamburska 2004; Shiganova 2005; Vidjak *et al*. 2006). Copepods are also important elements of marine plankton community by showing wide distribution and by constituting many species. Copepod species are the best biological indicators in various ecosystems. They also vary in abundance according to differences of physical and chemical properties in the environment (Dussart and Defaye 1995).

During last decades, the Black Sea ecosystem changed drastically as a result of increase in nutrients (nitrate and phosphorus) concentrations which were discharged by rivers (Bat *et al*. 2007). Shifts from the deterioration in the balance of nutrient concentrations showed its negative effect in phytoplankton and zooplankton quality and quantity. In the studies about the Black Sea zooplankton, spatiotemporal changes in abundance and biomass, as well as ecological factors effecting zooplankton were examined (Niermann and Greve 1997; Yıldız 1997; Kovalev *et al*. 1998 a, b, c; Niermann *et al*. 1998; Konsulov and Kamburska 1998; Shiganova 1998; Shiganova *et al*. 1998; Üstün 2005; Deniz 2009; Yıldız 2010; Üstün 2010).

In this study, we aimed to understand the distribution and abundance of copepod species in the costal waters of the southern Black Sea.

Materials and Methods

General Characteristics of Research Areas

The Black Sea is a semi-enclosed sea, being located in north of the Anatolia, Turkey (40°- 46°N, 27°- 41°E). It is connected to the the Marmara Sea by the Istanbul Strait (Bosphorus) and to the Mediterranean by the Çanakkale Strait (Unluata *et al*. 1990). On the southern coast of the Black Sea, Samsun is located between 37°08′- 34°30′E and 40°05′- 41°45′N. The longest river of the Turkey, the Kızılırmak (1,182 km) which is originated from Kızıldağ of Sivas City, is discharging into the Black Sea from the Cape Bafra of Samsun City.

Sampling Stations

Sampling stations were chosen around the Kizilirmak River Delta and around the Samsun City coast (Figure 1). Station K1 is placed in the west of Kizilirmak River mouth and has 14m depth while the station K2 and station K3 are located in the northern and eastern parts of the river mouth, respectively. The station L1, however, is located in the Samsun Harbour and the station L2 is placed in the norhern part of the harbour with a distance of 250m and 12m depth.

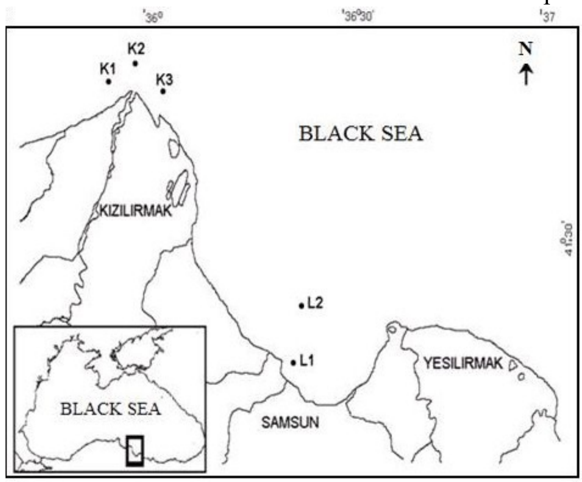

Figure 1. Location of sampling stations

Table 1. Depth and coordinates of the sampling stations

Sampling Station	Depth (m)	Coordinates
K1	14	41° 44′ 56.00′′N, 35° 56′ 02.00′′E
K2	100	41° 45′ 32.00′′N, 35° 52′ 19.00′′E
K3	8	41° 44′ 11.50′′N, 35° 59′ 29.00′′E
L1	12	41° 18′ 15.00′′N, 36° 21′ 49.00′′E
L2	40	41° 23′ 34.00′′N, 36° 23′ 51.00′′E

Sampling and Identification

Copepod samples were collected vertically at sampling stations with a standard plankton net (a mesh of 115µm, 1.5m long and 57cm diameter) between January 2008 and December 2008. Sampling in November 2008 failed due to the adverse weather conditions. After collecting the copepod samples, the net was rinsed gently and samples were transferred into 500ml plastic jars, and fixed by formaldehyde to a final concentration of 4%. The samples were then transferred to 50ml glass bottles and systematic identification was accomplished under invert microscope (Prior, UK) using a Bogorov-Rass counting chamber. Copepods were identified by certain characteristics such as general anatomy, a1, a2, p5, structure of organs (urosom, prosom), according to Rose (1933), Boltovskoy (1999), Dussart and Defaye (1995), Bradford *et al.* (1999), Özel (2003), Boxshall and Halsey (2004). Prior to the counting process, the sample vials were rendered homogenous by shaking gently and 7.5ml of sample was put on a 8x10 mm sized counting tray. The samples were then counted under an inverted microscope (Prior, UK). Countings were repeated three times for each sample and the abundance in 1m^3 sea water was calculated according to the following formula (Lagler 1956);

$$\text{Abundance } 1m^3 = \frac{50cc \text{ (counting bottle volume)} \times 1cc' \text{number of individuals} \times 1m^3}{1cc \times h\pi r^2}$$

$h\pi r^2$= Sample volume
r= Net radius
h= Vertical depth

Furthermore, certain physical and chemical parameters of the water samples were measured during the sampling period. Of these, pH was measured with a Consort C534. TDS (Total dissolved substance), electrical conductivity and temperature were determined using Cyberscan Con 11 salinometer and chemical parameters (NH_3-N, SiO_2, PO_4-P) with Hanna C200 (APHA 1995). The water transperancy was determined with a 20cm diameter Secchi disk.

Ecometrics
Statistical analyses were carried out using PRIMER v.5. Hierarchical agglomerative clustering was applied to Bray-Curtis similarity matrix from abundance data of copepod species (Bakus 2007).

Results

In the Kızılırmak river mouth and Samsun harbour area, total of 10 copepod species were determined: *A. clausi* (Giesbrecht, 1889)*; P. parvus* (Claus, 1863)*; C. euxinus* (Hulsemann, 1991)*; C. ponticus* (Karavaev, 1894)*; C. aquaedulcis* (Kritchagin, 1873)*; E.acutifrons* (Dana, 1847)*; O. similis* (Claus, 1866)*; P. elongatus* (Boeck, 1965); *C. perplexa* (T. and A. Scott, 1893) and *A. denticornis* (Wierzejski, 1887).

Monthly observations of physical and chemical properties of the water samples revealed various peaks in different parameters. During the study period, the physicochemical results ranged; water temperature 8.3°C (L1, January) - 27.2°C (K1, August), pH 8.19 (K2, April; L2, December) - 10.37 (L1, April), transparency with secchi disk 0.75 m (L1, May) - 11 m (K2, July), TDS values 8.21 ppt (L1, March) - 31.80 ppt (L1, August), conductivity 15,01 mS (L2, July) - 33.63 mS (K2, October), ammonia nitrogen (NH_4^+-N) 0.13 - 1.25mgL^{-1}, cilicium dioxide (SiO_2) 0.01 - 2.2 mgL^{-1} and phosphate phosphorus (PO_4-P) 0.01 - 4.68 mgL^{-1}.

Average abundance of copepod species varied seasonally during the sampling period. Certain species occupying an important part of the total copepod population was in low abundance for some seasons. For example, *A.clausi, P.s parvus, E. acutifrons* were observed in all sampling periods while *A. denticornis, C. euxinus, P. elongatus, C. aquaedulcis, C. ponticus, C. perplexa* were observed only in certain seasons.

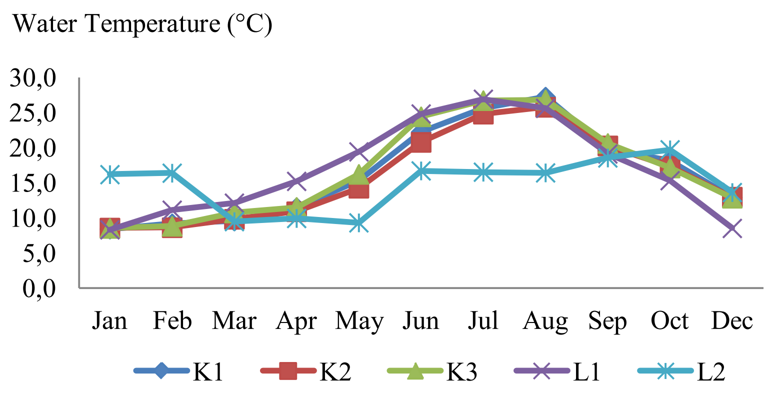

Figure 2. Monthly variations of water temperature

In winter, the average abundance were 407 ind/m^3. *P. parvus* was dominant (761 ind/m^3) and *A. clausi* (381 ind/m^3) was subdominant species in January. *P. elongatus* (2 ind/m^3) revealed the lowest abundance in this month.

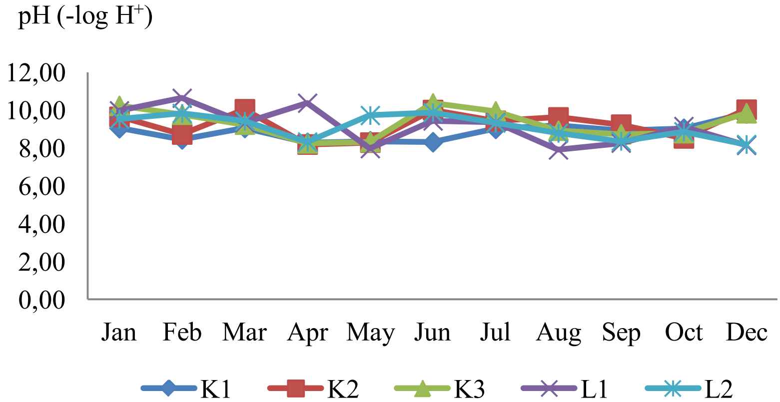

Figure 3. Monthly variations of pH in water samples

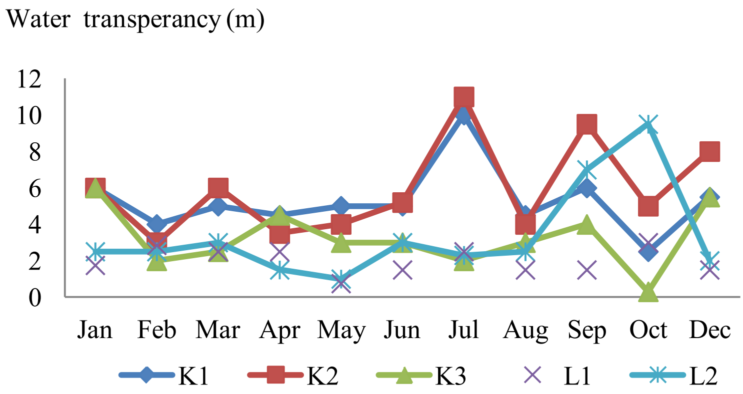

Figure 4. Monthly variations of water transperancy at the sampling stations

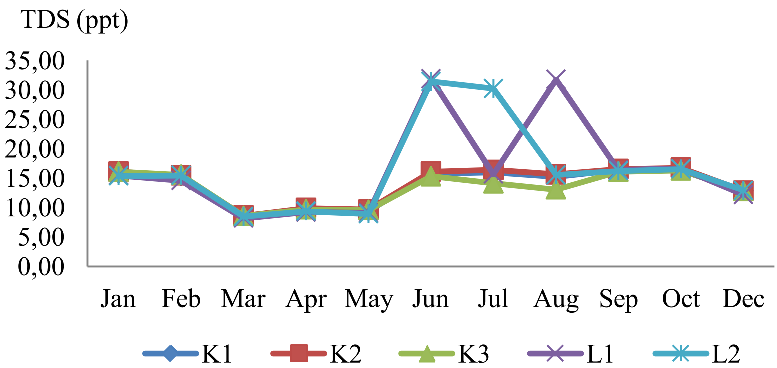

Figure 5. Monthly variations of TDS in water samples

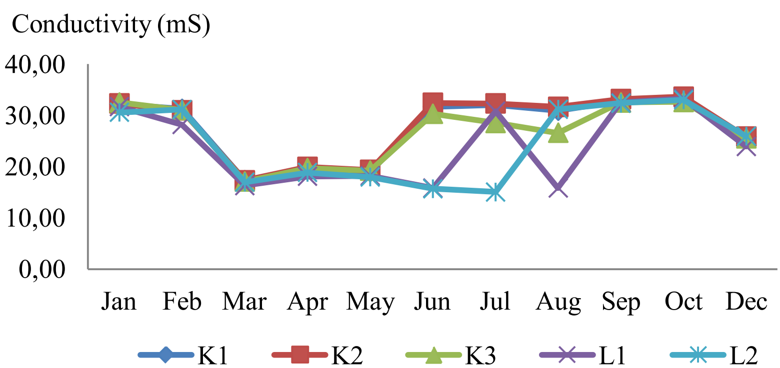

Figure 6. Monthly variations of conductivity in water samples

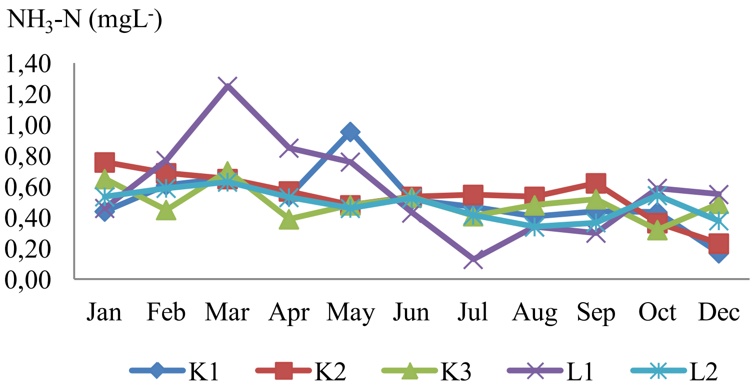

Figure 7. Monthly variations of NH_3-N in water samples

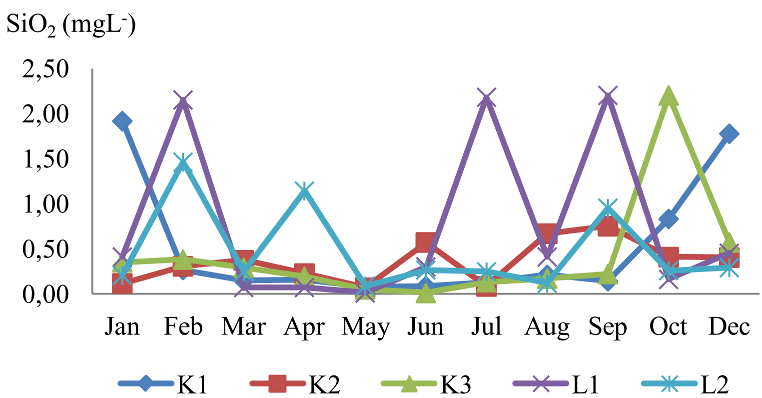

Figure 8. Monthly variations of SiO_2 concentration in water samples

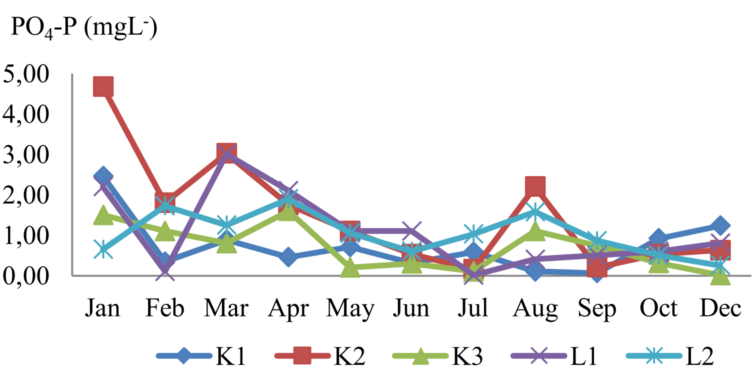

Figure 9. Monthly variations of PO_4-P concentration in water samples

In February (total avarage abundance 180 ind/m^3) the dominant species replaced with the subdominant species (*A.clausi* 1135 ind/m^3, *P. parvus* 501 ind/m^3). In December, maximum abundance was the highest in contrast to the other winter months (914 ind/m^3). In this month, with a total abundance of 7365 ind/m^3, *P. parvus* was dominant and the subdominant was *A.clausi* (1393 ind/m^3). *C. perplexa* and *C. ponticus* were not observed in this season.

In spring season, the average abundance was 81 ind/m^3. *P. parvus* (469 ind/m^3) and *A. clausi* (104 ind/m^3) were dominant and subdominant species in March. In April, the abundance showed a slight increase. *C. perplexa* was dominant species with 438 ind/m^3. In May, the average abundance at the same level while the dominant species was *A. clausi* (600 ind/m^3).

During summer, total average abundance reached to 116 ind/m^3 in June and *A. clausi* with 906 ind/m^3 was the dominant species. In July, a decrease in the number of individuals (41 ind/m^3) occurred and the dominant species was *E.acutifrons* (222 ind/m^3). Total average abundance has increased (124 ind/m^3) in August and *A. clausi* (1083 ind/m^3) became dominant species. *C.euxinus* and *O. similis* showed the lowest abundance in summer. *C. aquaedulcis* and *P.elongatus* were not observed in this season.

The average abundance kept increasing in autumn (438 ind/m^3). In September *A. clausi* was dominant species with 2635 ind/m^3 and *E. acutifrons* was subdominant with 655 ind/m^3. In October *P. parvus* and *A. Clausi,* with 2725 ind/m^3 and 1916 ind/m^3, have been dominant and subdominant species, respectively. *P. elongatus* showed the lowest abundance in both September and October. *A. denticornis*, *C. aquaedulcis* and *C. perplexa* were not observed in this season (Figure 10).

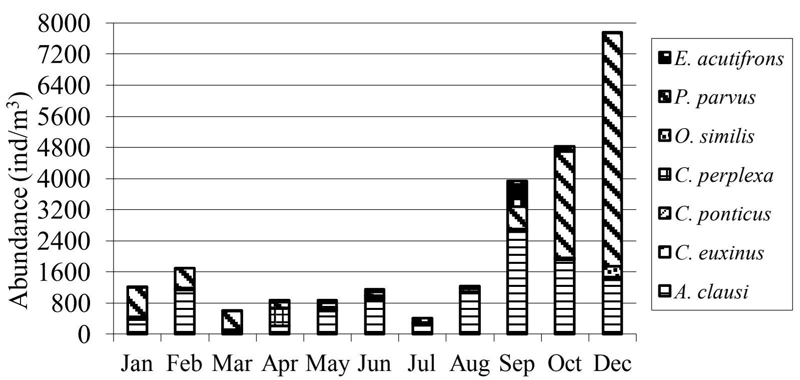

Figure 10. Seasonal variation in average abundance of the copepod species (*A. denticornis, C. aquaedulcis, P. elongatus* are not shown here as their average abundance was quite low)

During the whole study period, the abundance at the stations varied as shown in Figure 11. Range of the abundance at each station was K1 (896 - 18 ind/m^3), K2 (907 - 11 ind/m^3), K3 (2258 - 23 ind/m^3), L1 (1257 - 44 ind/m^3) and L2 (218 - 11 ind/m^3).

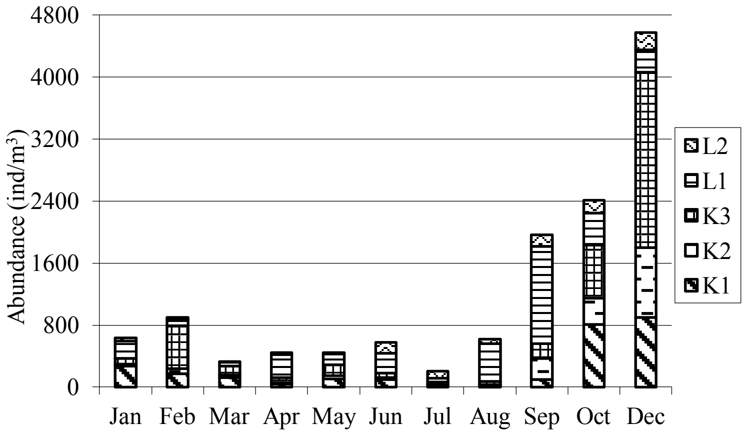

Figure 11. Copepod abundance by sampling sations

According to the results of hierrarchical cluster analysis of the similarity matrix derived from the copepod abundance data (Figure 12), three groups were identified at a similarity level of 34%. First group included only one sample, L1 with an abundance of 54 ind/m^3. The second consisted of the samples with abundances ranging from 11-40 ind/m^3, the third group ranged from 55 to 2258 ind/m^3.

According to the results of the cluster analyses (Figure 13), three clusters at 47% similarity level were determined. While *C. euxinus*, *O. similis*, *C. aquaedulcis* and *P. elongatus* formed the winter species group*, C. ponticus*, *E. acutifrons*, *A. denticornis* and *C. perplexa* were observed only in certain seasons. The species observed in all samples were *A. clausi* and *P. parvus.*

According to the results of MDS analysis of Bray-Curtis similarity matrix, three groups were formed with a confident stress value (0,15) (Figure 14). The configuration of the species group showed a convenient grouping with the 0.08 stress value (Figure 15).

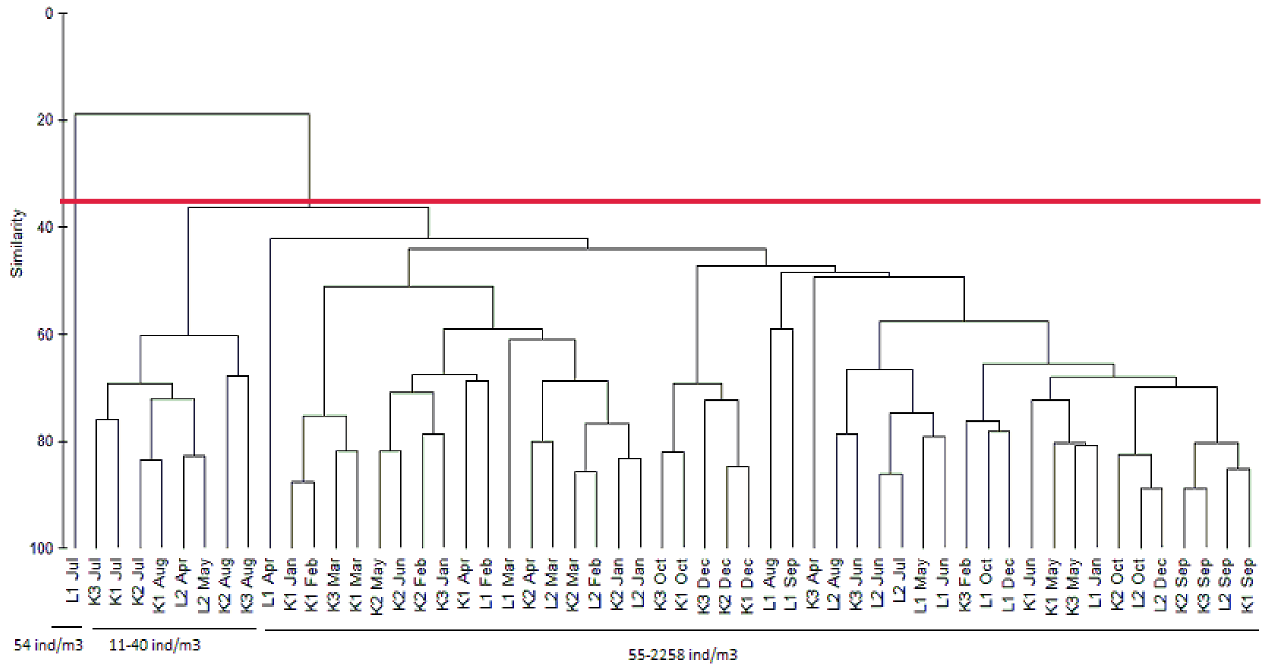

Figure 12. Cluster analysis based on the similarity matrix of copepod abundance data

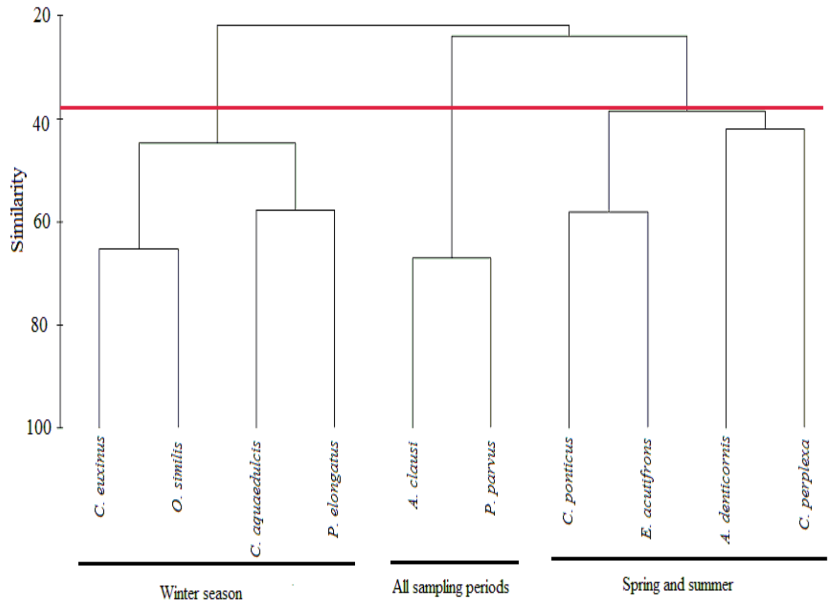

Figure 13. The hieararchical cluster analysis of similarity matrix derived from presence/absence data of copepod species

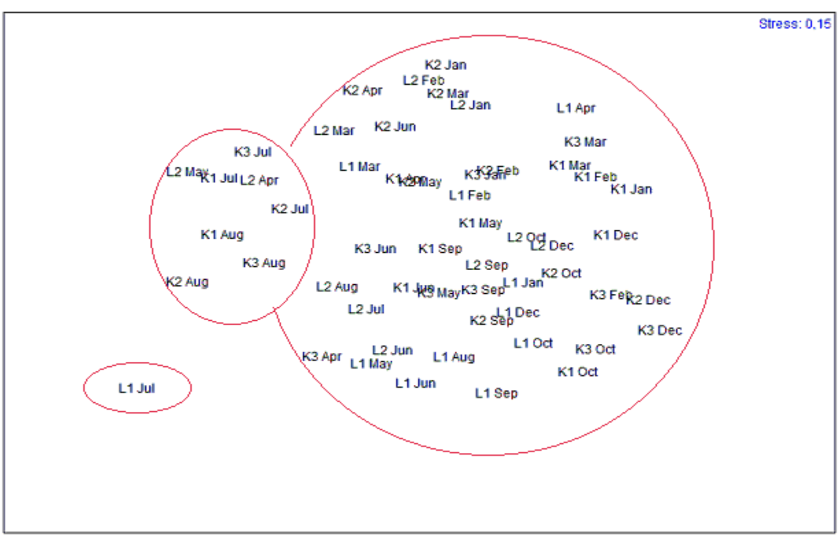

Figure 14. MDS plot from the similarity matrix of copepod abundance data

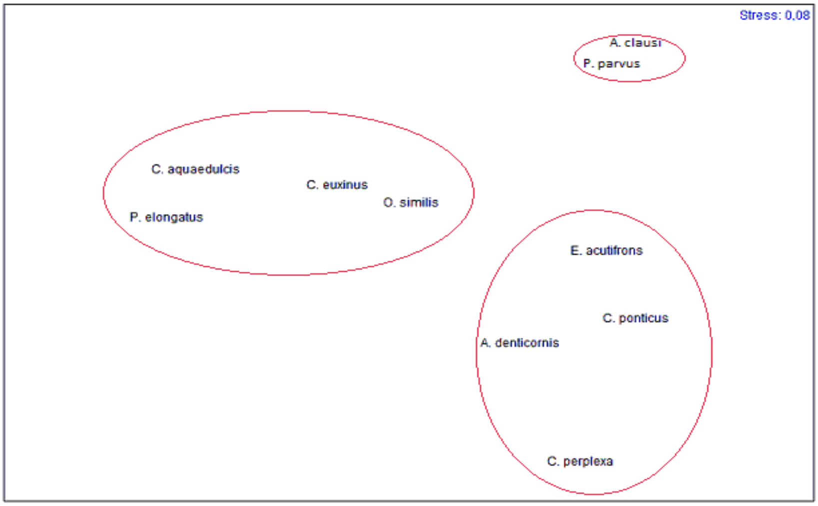

Figure 15. MDS plot from the similarity matrix of copepod species data

Discussion

We identified a total of 10 copepod species (*A. clausi*, *C. euxinus*, *P. parvus*, *P. elongatus*, *C. ponticus*, *C. aquaedulcis*, *A. denticornis*, *O. similis*, *E. acutifrons* and *C. perplexa* (copepodite I., II., III. stage) in the samples collected from the research area. Unlike the previous studies (Ergun 1994; Yıldız 1997; Unal 2002; Ustun 2005), *A. denticornis, C. aquaedulcis, C. perplexa* and *E.acutifrons* species were identified.

Baytut *et al*. (2010) used the TRIX index in Samsun Bay in order to determine the trophic levels in region and found that the study area was highly eutrophic. Tarkan *et al*. (2005) found *E. acutifrons* in high abundance in fall, eutrophic *A. clausi* and *P. parvus* in spring in the Istanbul Strait where exist the euryterm and the euryhaline. Unlike Tarkan *et al*. (2005), we found *A. clausi* and *P. parvus* in the whole year in this eutrophic study area and the number of individuals of *A. clausi* increased in fall and winter while *P. parvus* elevated only in autumn. *E. acutifrons* also increased in summer and autumn. Goubanova *et al*. (2001) determined *C.ponticus* as a warm water species in Sevastopol Gulf and they did not found this species in cold season. In this study, we found similar results with Gubanova *et al*. (2001); *C. ponticus* was observed in only spring and summer seasons in our region and the highest number of individuals reached in August. Hansen *et al*. (2004) reported in the Baltic Sea that abundance of *O. similis* increased in summer after April and the maximum abundance was found in August. Yıldız (2010) noted an abundance report of *O. similis* that this species increases in spring and summer in the southern Black Sea. In this study, we found *O. similis* in the same months with the exception of July and August and the highest abundance was observed in December. According to Huys and Boxshall (1991), *A. denticornis* is a freshwater species. In this study *A. denticornis* was found at the coastal stations only Bafra (K1 and K3) probably transported from the Kizilirmak River by river currents, and have adapted to this environment. Ceccherelli *et al*. (1982) reported that epibenthic harpacticoid copepod, *C. perplexa* is distributed in brackish waters. *C. perplexa* were observed in copepodit I., II. and III. larval stages at the stations L1 and L2 in autumn and summer. *C. aquaedulcis* was reported from Samsun Bafra Balık Lagoon and Gıcı Lagoon (Ustaoğlu *et al*. 2012) in addition to the Azov Sea, Hazar Sea, Danube and Volga branches (Grigorovich *et al*. 2002; Piontkovski *et al*. 2006; Bagheri *et al*. 2013). The presence of *C. aquaedulcis* in the samples of L1 and L2 in April and December raised the likelihood that this species may be exotic and came to the area by ballast water transportation. Many researchers reported that *P. elongatus* is a cold water species, existing in the cold winter mix layer (Shiganova 2005; Vinogradov *et al*. 1985; Siokou-Frangou *et al*. 2004). *P. elongatus* was observed in autumn and winter and its seasonal distribution was similar to the previous studies (Shiganova 2005; Vinogradov *et al*. 1985; Siokou-Frangou *et al*. 2004).

While some fluctuations were observed in the abundance of species, a decline in July was followed by an increase between August and December. Aker (2002) denoted that copepod abundance revealed a peak in late spring and a second peak in autumn-winter in the Middle Aegean territorial waters of Turkey between 1997 and 1999. In this study, however, the abundances in spring and summer were rather lower than the peaks in September and October. It is very likely that shifts in the abundance of copepods may be caused by not only rainfall, temperature and nutrients but also by anthropogenic impacts. The excessive raise in the abundance of copepods in December may be related to overfishing of middle sized fish such as anchovy. We observed that the predator of copepods significantly decreased while copepod abundance boosted in December.

The abundances in the samples collected from Bafra (the average annual number of individuals K1: 241ind/m^3, K2: 160 ind/m^3, K3: 381 ind/m^3) were higher than those from Samsun City coast (L1: 324 ind/m^3, L2: 85 ind/m^3). We assume that the agricultural activities increase the concentration of the nutrients for phytoplankton as the prey of copepods, the abundance is thus rather high in Bafra samples. Accordingly, the station L1 defines a degraded area which is generally used as an harbour area and is a discharging point of anthropogenic pollutants including ballast water of ships. The eutrophication indicators, *A. clausi* and *P. parvus*, were abundantly observed at the stations K1, K2, K3 in spring and fall 2008.

The monthly average temperature ranged from 8.3°C (January, L1) to 27.2°C (August, K1) in our study. It is likely that the temperature variation between samples originated from the currents, daily temperature changes, wind, rain, waves and stratification. The differences in temperature among various depths may be, however, due to the changes in downstream currents originated from coastal waves.

The highest pH were measured as 10.63 at L1 in February while the lowest was 7.9 at L1 in August. Baytut (2004) observed pH ranging between 8.90 (in April) and 7.45 (in May) in the Samsun coasts. The lowest pH values were close to each other in both studies. However, the highest ones are quite different, possibly due to the diverse rainfall regimes during these study periods. Maximum values among physico-chemical parameters (0,96 mgL^{-} NH_3-N (K1, May); 4,68 mgL^{-} PO_4-P (January, K2); 2,20 mgL^{-} SiO_2 (October, K3) were measured in the samples from Bafra (the delta of the Kizilirmak River).

The hierrarchical clustering and nonparametric multidimensional scaling analyses from the Bray-Curtis similarity matrix of the copepod abundance data revealed that the samples split into two main groups at a similarity level of 19% apart from only one sample at L1 in July. The latter may be due to the different community structure (*P. parvus* (18 ind/m^3) and *E. acutifrons* (525 ind/m^3)) and the middle abundance (54 ind/m^3) than the other samples in this station in July. Sautour and Castel (1993) reported that the dominant copepod species in the coastal zone, *E. acutifrons* prefers *Skeletonema costatum*, *Chaetoceros calcitrans* and haptophyte species *Isochrysis galbana* in its diet. Furthermore, the diatoms were also found to bloom in this sample, which were measured by excessive SiO_2 concentrations. *E. acutifrons* was very abundant at the station L1 in July and this proliferation may be due to a diatom bloom indicated by higher SiO_2 levels. Excessive proliferation of diatoms is, however, mentioned to cause sharp decrease in copepod abundance and diversity of species (Hallegraef *et al*. 1995).

According to the hierrarchical clustering from the Jaccard similarity matrix of the presence absence data of the copepod abundance, there were three groups at a similarity level of 47%. The first group consists of winter species e.g. *C. euxinus, P. elongatus, C. aquaedulcis* and *O. similis*. This group is composed of the cold water species or daily migrating species (Erkan *et al*. 2000; Niermann *et al*. 1998; Shiganova 2005). The second group included the common species (*A. clausi and Paracalanus* sp.) which were observed in the whole year. The third group, however, consisted of the discontiniously resident species which were observed in certain seasons. These were stenoterm *C. ponticus*, *E. acutifrons*, *A. denticornis* and *C. perplexa*. *E. acutifrons* and *C. ponticus* (Özel and Aker 2004; Huys and Boxshall 199l; Boltovskoy 1999). It has been considered that *A. denticornis* may be transported by river currents especially in winter and spring when rainfall is abundant. The presence of the first three stages of *C. perplexa* are assumed due to the reproductive period observed in April, May, and June.

This study revealed a multianalysis approach in order to resolve relationships between environmental parameters and copepod species diversity in the southern Black Sea was useful and recommends its use in the future studies.

Acknowledgement

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Güney Karadeniz (Türkiye) Samsun Kıyı sularında kopepod bolluğunun ve tür kompozisyonunun yıllık değişimi

Özet

Ocak 2008- Aralık 2008 tarihleri arasında Karadeniz Samsun kıyı bölgesinin kopepoda faunası incelenmiştir. Kopepod faunasının tür kompozisyonu ve bolluk değerleri ve fizikokimyasal faktörlerin bunlar üzerine etkileri araştırma bölgesindeki beş istasyondan toplanan aylık örneklerde belirlendi. Kopepod bolluk verilerinden Bray Curtis benzerlik matisi oluşturuldu ve birleştirici hiyerarşik kümeleme analiz ve çok boyutlu ölçeklendirme analizi yapıldı. Samsun Kıyı şeridinde Calanoida ordosuna ait yedi tür *Calanus euxinus (Hulsemann*, 1991); *Paracalanus parvus* (Claus, 1863); *Centropagaes ponticus* Karavaev 1895; *Calanipedia aquaedulcis* (Kritchagin 1873); *Acanthodiaptomus denticornis* (Wierzjhski, 1857); *Acartia* (*Acartiura) clausi* (Giesbrecht, 1899); *Pseudocalanus elongatus* (Boeck, 1965), Cyclopoida ordosuna ait bir tür *Oithona similis,* (Claus, 1863), Harpacticoida ordosuna ait iki tür *Euterpina acutifrons* (Dana, 1852); *Canuella perplexa* (T. and A. Scott, *1893*) olmak üzere toplam on tür tespit edilmiştir. Örnekleme süresince en fazla birey sayısı Aralık ayında gözlenmiştir. En düşük bolluk değerleri sırasıyla Temmuz ve Mart 2008'de kaydedilmiştir. Fizikokimyasal parametreler (sıcaklık, seki disk, pH, iletkenlik, TDS (Toplam çözünmüş katı madde), NH_3-N, PO_4, SiO_2) ve kopepod türlerinin bollukları arasındaki korelasyon katsayısı önemli seviyede ölçülmüştür.

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