

RESEARCH ARTICLE

The qualitative and quantitative distribution of the zooplankton in the Southeastern Black Sea (Trabzon coast)

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Abstract

In the present study, the qualitative and quantitative changes of zooplankton community were examined on a monthly basis at three stations off the coast of Trabzon, the Southeastern Black Sea from October 2007 to September 2008. A total of 36 samples were collected. The highest value of the abundance of the total zooplankton was recorded in May. *Noctiluca scintillans* was the most abundant zooplankton with a share of 54% (maximum: 3752,80 ind.m⁻³ in May). They were followed by Copepoda with 21% (maximum: 551 ind.m⁻³ in March and Cladocera with 13% (maximum: 680 ind.m⁻³ in August. Copepoda was present in the sampling throughout the year whereas *N. scintillans* and *Cladocera* were dominant for a period of 2-3 months. The annual average abundance of zooplankton was 1116±282 ind.m⁻³ (55989 ind./m²). In addition temperature as main physical parameter of environment was determined according to the depth.

Keywords: Black Sea, zooplankton abundance, monthly vertical distribution.

Introduction

The Black Sea is very sensitive especially being the estuaries of the main European rivers and due to anthropogenic impacts (Shiganova and Bulgakova 2000; Eker-Develi and Kideys 2003).

The Black Sea receives 87 % of the fresh water volume from its north-western part. The rivers reduce surface salinity and contribute large amounts of nutrients and detritus in the north-western part of the Black Sea. In the southern part of the basin, hydrobiological properties are more stable than the rest (Uysal and Sur 1995).

The temperature of the surface water varies seasonally and locally. While water temperature is 6-7 °C in winter and 22-23 °C in summer on average for the Black Sea, in the southern and eastern coasts it is 8-9 °C in winter and 24-25 °C in summer (Balkaş *et al.* 1990).

The surface water has an average salinity of 18 to 18.5 parts per thousand (compared to 30 to 40 for the oceans) and contains oxygen and other nutrients required to sustain biotic activity.

The southeastern Black Sea is one of the most valuable fishing areas in the Turkish fishery. This region has 49.2 % of total fishery production in 2003 (Anonymous 2006).

Almost all fish with high economic value start their life as plankton. Fish larvae, absorbed yolk sac, depend on the plankton population for survival. In this case, any kind of changes that may affect the plankton, consequently will also affect the fish population. Therefore a region which has the highest plankton density as fish feed is the richest fishing area as well.

Zooplankton is very important since it is not only the secondary producer in food chain but also it is food for fish and shrimp larvae. The existence of zooplankton and its abundance do not only depend on phytoplankton. The impact of the hydrographical structure and stress caused by pollution is important as well. Creatures living in aquatic environment lead their existence in a balance of nature. This balance has been changed during the last decades due to the factors such as overfishing, eutrophication, and lack of oxygen. As a consequence, some zooplankton species are disappearing or available only in small numbers (Caddy 1993; Zaitsev and Alexandrov 1995). In contrast to this, some other organisms are developing and reaching to the high quantities.

In addition to that, the variety and community structure of copepod and cladocerans, whose existence is typical for the Black Sea ecosystem, have changed considerably since the pre-eutrophication period. A lot of dominant mesozooplankton species which support the fish stocks have been replaced by small and less valuable species (Konsulov and Kamburska 1998; Eker *et al.* 1999; Erkan and Gücü 2000).

Although a considerable number of studies have been conducted on this issue in the Black Sea exposed to very rapid changes in recent years, there are few studies about the year round abundance and the seasonal distribution of zooplankton in this region. The aim of this study is to investigate the seasonal qualitative and quantitative changes of the zooplankton in this region.

Materials and Methods

Monthly samples were collected from three stations off Yomra-Trabzon in the Black Sea by the R/V RESEARCH-1 of the Central Fisheries Research Institute, between October 2007 and September 2008 (Figure 1). The total depth of

Station 1 (40°58'385"N- 39°51'982"E) was 50 m, it was 100 m at Station 2 (40°58'524"N- 39°51'598"E) and 200 m at Station 3 (40°58'662"N- 39°51'275"E).

Zooplankton samples were taken by vertical haul from 50 m to the surface at each station by using WP-2 type plankton net of 0.57 m diameter mouth opening and 200 µm mesh size. The net catch was preserved in buffered formalin (4%) and after their sedimentation in jars, the samples were put into 250cc plastic sample jars and kept in dark until further analysis (Özel 1996; Venrick 1978). All groups were sorted and counted from the replicated 10 ml sub-samples. A total of 36 samples were analyzed. Physical and chemical parameters of environment which include temperature, salinity and chl-*a* were measured at 0,5 m, 25 m, 50 m, 100 m and 200 m depths by using Sea-Bird SBE 25 type CTD prob. Chl-*a* analysis was carried out in seawater samples filtered through millipore-type filters of pore size 0.45 µm.

For the qualitative and quantitative analysis of the zooplankton, a trinocular stereo zoom microscope (Olympus model SZX7) was used. The identification of zooplankton groups was made according to Tregouboff and Rose (1957), Özel (1992, 1996), Larink and Westheide (2006) and Vershinin (2005).

Statistical analysis was done with the software Statistica 7. The statistical significance of differences in abundance between stations and months were determined by using ANOVA at a significance 0,05. The results are presented as mean ± standard deviation (SD).



Figure 1. Map of the research area and stations

Results

Physical and Chemical Parameters

The water temperature in the surface layer varied from 8.11 to 27.70 °C (the minimum in February and the maximum in August). The annual average water temperature was 16.93 ± 1.89 °C in the surface layer. The minimum and the maximum water temperature at 50 m depth were 7.77 °C in April and 14.77 °C in November, respectively (Figure 2).

Stratification took place according to depth. Although temperature difference between surface water and 200 m was very small between January and April, as from May, associated with surface water warming, a seasonal thermocline layer was determined. This thermocline stratification can be easily distinguished at 20-40 m.

The salinity varied between 17.31‰ and 18.04‰ in the surface water during the period between October 2007 and September 2008, at three stations. Due to spring rain and the effect of fresh water inputs, the monthly surface water salinity differences was found very small according to stations. The variability in salinity between surface water and 50 m was found very low (17.81-18.45‰).

Chlorophyll-a content in the surface waters varied 0.94–3.07 µg/l in Station 1, 0.97–3.96 µg/l in Station 2 and 0.99–4.53 µg/l in Station 3 from October 2007 to September 2008. Vertical distribution of chl-a in the water column showed downward tendency but showed increase when phytoplankton bloom occurred.

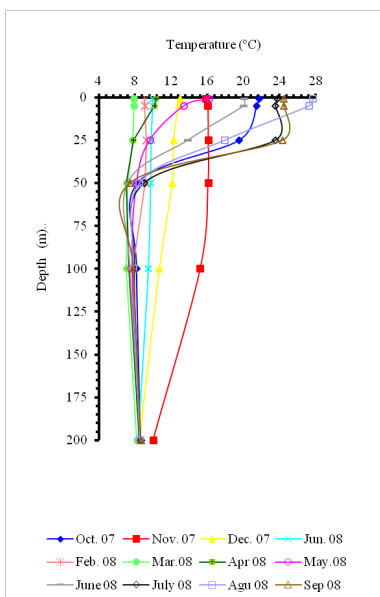


Figure 2. Seasonal changes of temperature, salinity and chl-a according to the depth

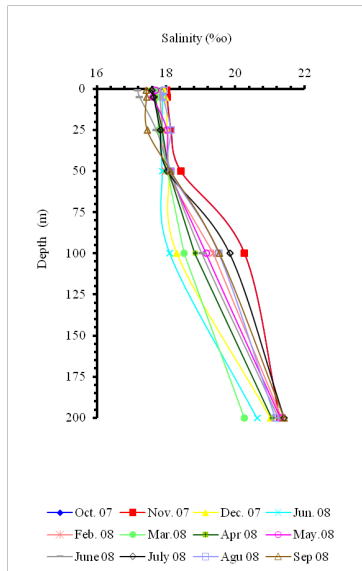


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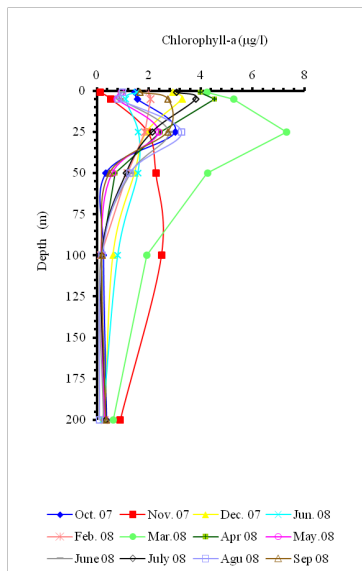


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Monthly Zooplankton Distribution (50-0m)

The analysis of the monthly distribution of the zooplankton shows that the abundance of the total zooplankton was noted to a certain extent all year round and displayed one main peak (May) and two small elevations (January and August). Total abundance reached its maximum values in May (3826 ind.m⁻³), and to its minimum values in December (233 ind.m⁻³) (Table 1 and Figure 3).

Total zooplankton abundance showed no preference statistically ($P > 0.05$) between stations while the total zooplankton density in Station 3 was the highest (1383±452 ind.m⁻³), followed by Station 2 (1049±242 ind.m⁻³) and 1 (916±195 ind. m⁻³).

The abundance at Station 1 ranged between 253-2372 ind.m⁻³, whereas those at the Station 2 and Station 3 ranged between 222-3210 ind.m⁻³ and 223-5896 ind.m⁻³, respectively (Table 2). It was observed that the zooplankton had one main peak at all stations (Figure 4).

Table 1. Monthly average abundance distribution of main zooplankton groups (ind.m⁻³) (average values of stations)

	Copepoda	Cladocera	Noctiluca scintillans	Other	Total
Oct.07	213± 49 ^{ac}	13±6 ^a	108±25 ^a	77±12 ^a	546±123 ^{ab}
Nov.07	257±7 ^a	16±6 ^a	61±10 ^a	212±59 ^a	376±9 ^a
Dec.07	161±5 ^{ac}	**	52±5 ^a	42±5 ^a	233±10 ^a
Jan.08	309±17 ^{ab}	**	146±23 ^a	20±7 ^a	797±153 ^{ba}
Feb.08	283±29 ^{ab}	**	8±3 ^a	341±114 ^b	665±212 ^{ba}
Mar.08	551±152^b	34±11 ^a	5±2 ^a	374±211^b	791±257 ^{ba}
Apr.08	450±55 ^b	94±16 ^a	1016±333 ^a	202±96 ^{ab}	1792±185 ^b
May.08	61±15^{ca}	3±3 ^a	3753±1027^b	232±102 ^{ab}	3826±1052^c
Jun.08	116±22 ^{ac}	78±15 ^a	1466±337 ^b	9±9 ^a	1742±388 ^{ba}
Jul.08	97±17 ^{ac}	430±64 ^b	265±17 ^a	82±20 ^a	830±88 ^{ba}
Aug.08	229±75 ^{ac}	680±221^b	95±31 ^a	38±13 ^a	1080±319 ^{ba}
Sep.08	134±4 ^{ac}	432±38 ^b	74±38 ^a	76±12 ^a	716±56 ^{ba}

**no occurrence, different letters in the same column (a, b, c) show the difference between the months ($P < 0.05$)

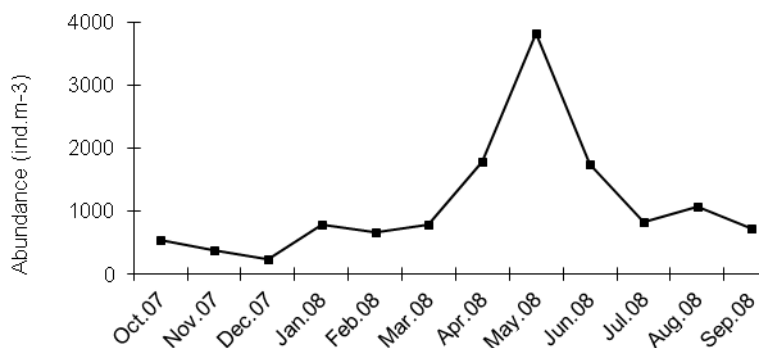


Figure 3. Monthly abundance fluctuation of total zooplankton (average values of stations)

Table 2. Abundance (ind.m⁻³) of main zooplankton groups according to stations (mean±S.E.) (average values of months)

	Copepoda	Cladocera	Noctiluca	Other	Total
Station 1	204±31 ^a	124±56 ^a	474±223 ^a	113±39 ^a	916±195 ^a
Station 2	236±49 ^a	118±52 ^a	504±269 ^a	191±68 ^a	1049±242 ^a
Station 3	276±59 ^a	203±99 ^a	783±484 ^a	122±37 ^a	1383±452 ^a
Mean	239±21	148±27	587±97	142±24	1116±137

Different letters in the same column show the difference between the stations ($P < 0.05$)

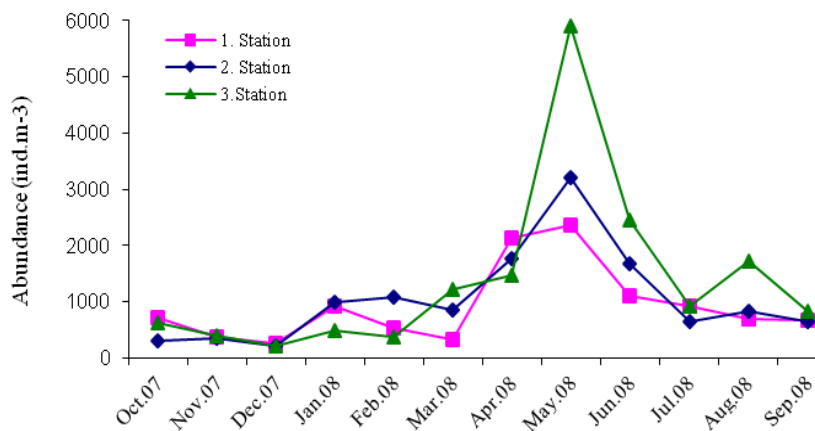


Figure 4. The monthly abundance fluctuation of total zooplankton at three stations (ind.m⁻³)

At all stations, *N. scintillans*, Copepoda and Cladocera were the most dominant groups. The distribution of the other zooplankton groups found in sampling such as Bivalvia, Appendicularia, Chaetognatha (*Sagitta* sp.), *Cirripedia nauplii*, Polychaeta larvae and Gastropoda showed similarity. *N. scintillans* had a mass dominance over the other mesozooplankton groups for about three months between April and June. Copepods were identified to be abundant throughout the year, except for the period of *Noctiluca* abundance. Cladocerans existed during warm months, appearing from July to September at the stations (Figure 5).

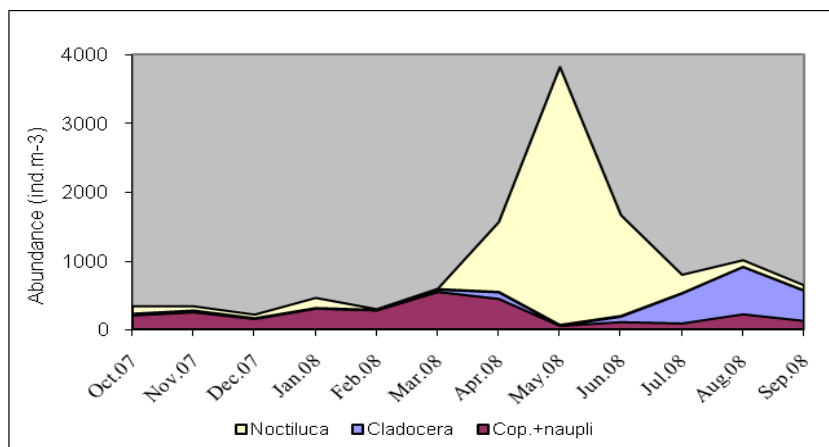


Figure 5. The monthly abundance fluctuation of main zooplankton groups (average values of stations)

As it can be inferred from Table 1 and Figure 5, the highest peak of Copepoda abundance was observed in March (551 ± 152 ind.m⁻³) and the lowest in May (61 ± 15 ind.m⁻³); the highest abundance of Cladocera was in August (680 ± 221 ind.m⁻³) and the lowest in December, January and February (0 ind.m⁻³). In the distribution of *N. scintillans*, there was only one and a high peak in May (3753 ± 1027 ind.m⁻³) and the lowest in March (5 ± 2 ind.m⁻³). The increase in the abundance of Copepoda, *N. scintillans* and Cladocera showed a sequential pattern. It is also striking that in the month with the highest abundance of *Noctiluca*, all the other groups were found only in low abundances. While Copepoda reached its peak value in autumn about a month earlier at Station 1 than the other stations, at Station 3 its spring peak was reached about a month earlier than other stations. *Noctiluca* and Cladocera displayed similar patterns for the formation of the peak time at the stations (Figure 6).

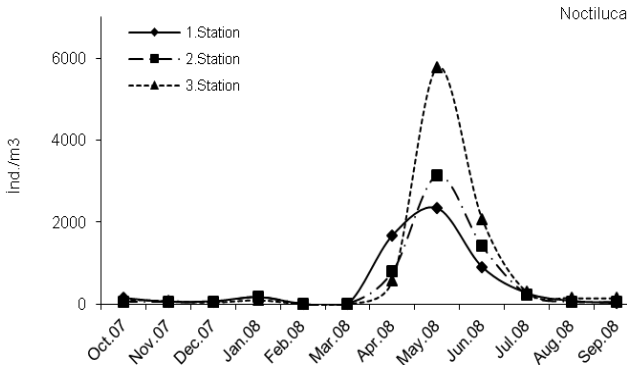
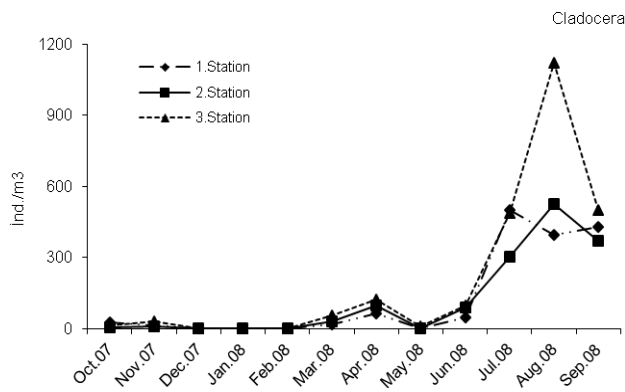
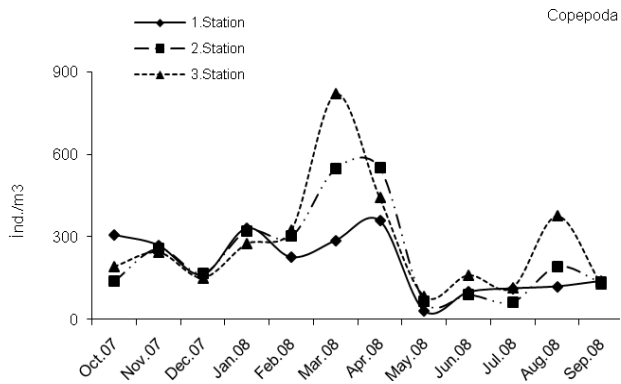


Figure 6. The monthly abundance fluctuation of main zooplankton groups at stations (ind.m⁻³)

The dominant zooplankton species occurring in the Southeastern Black Sea were determined as *Acartia clausi*, *Calanus euxinus*, *Pseudocalanus elongatus* of copepods, *Penilia avirostris* of cladocerans, *Noctiluca scintillans* and *Sagitta setosa*.

The proportional analysis of the monthly distribution of the zooplankton groups in 0-50m depth shows that in major part of the year (October, November, December, January and March) copepods were dominant and ranged between 38% and 70% in the total zooplankton. In these months, *N. scintillans* and *Bivalvia* came after copepods. In April, May and June, the rate of *N. scintillans* was 57%, 98% and 85%, respectively. In the warmer seasons (July, August and September), however, the cladocerans were dominant and constituted 52%, 64% and 57% of the zooplankton, respectively (Figure 7).

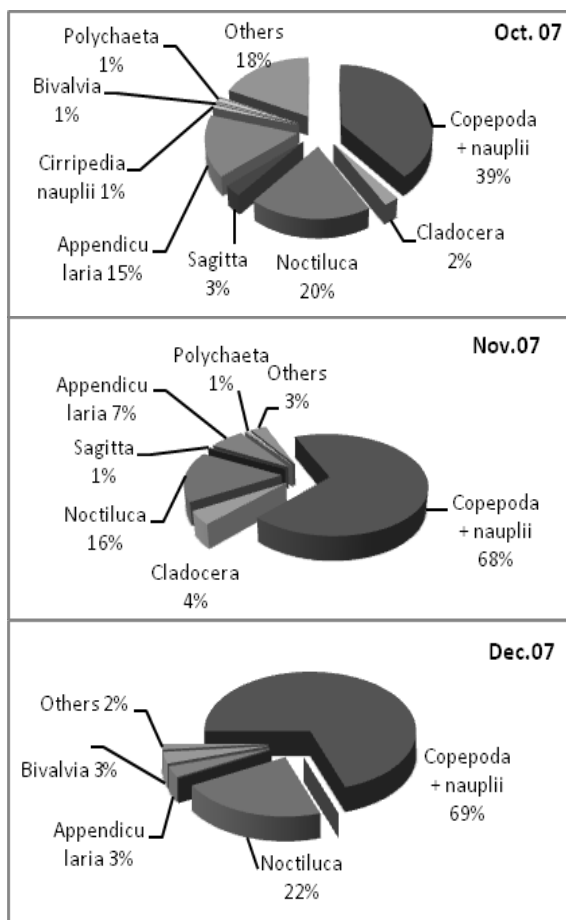


Figure 7. The proportions of zooplankton groups by months (%)

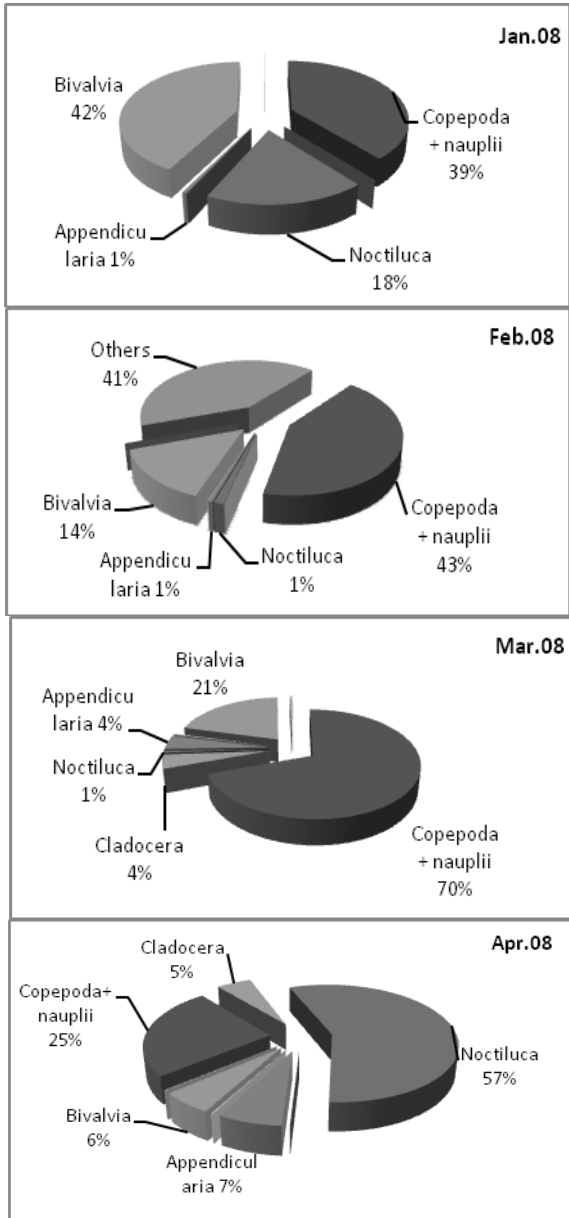


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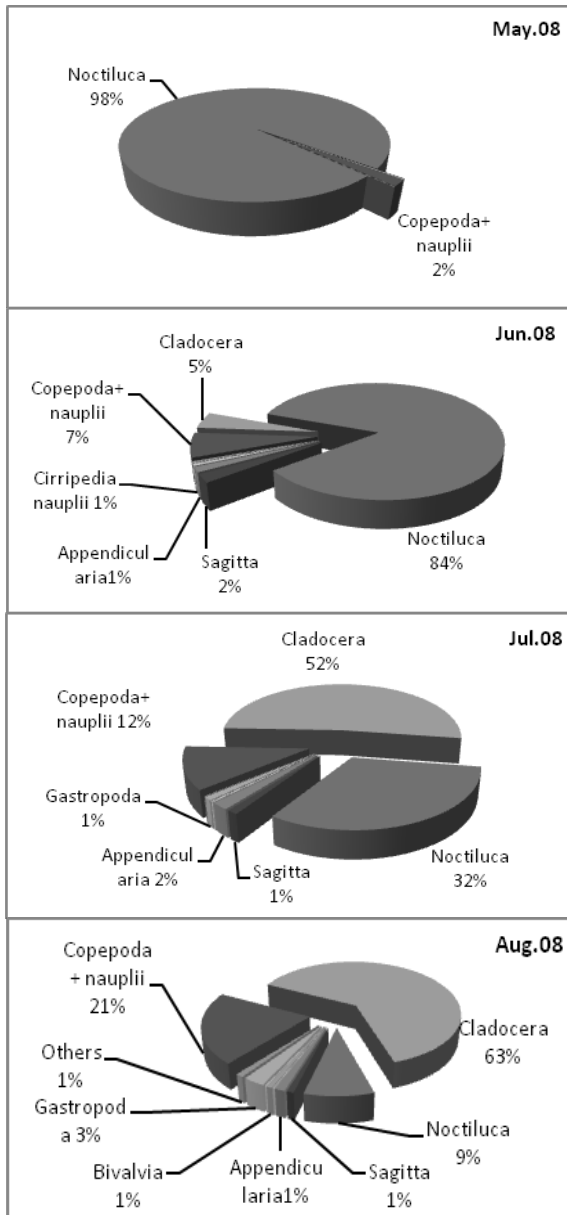


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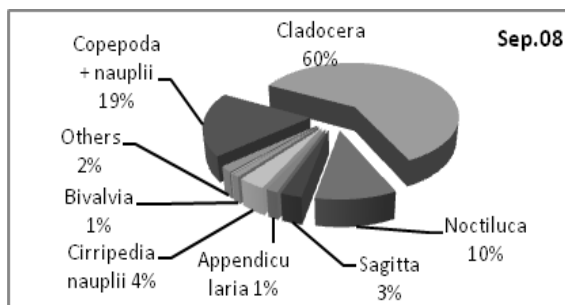


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Discussion and Conclusion

Mesozooplankton was previously (in the 1970's) known to possess two major peak periods in the middle of March and August, which followed by the phytoplankton explosion in winter and spring (Oğuz *et al.* 2001). However this situation has changed in the Black Sea since the beginning of the 1980's after the invasion of the undesired comb jelly *Mnemiopsis leidyi*. Second mesozooplankton peak appeared somewhat earlier, towards mid-June. This situation arose due to an additional phytoplankton bloom making up a total of three distinct blooms in February, late April and August. The appearance of mesozooplankton bloom in June was thus explained to have arisen following the April phytoplankton bloom (Konsulov and Kamburska 1998).

From January until May 1999 and from March until November 2000, Bat *et al.* (2007b) made a comparative study of two stations; the first station was at the coast, the second station was offshore. Bat *et al.* (2007b) have confirmed in aspects of abundance and biomass four peak periods at the coastal station and three peak periods at the offshore station.

Ünal (2002) determined four peaks in the abundance of the mesozooplankton in the Southern Black Sea and emphasized that autumn peak was much more distinct than winter peak.

Kovalev *et al.* (1999) stated in their review that in coastal areas, there are two peak periods in spring and autumn for the maximum zooplankton abundance. Moreover, it was reported that a third peak can be observed sometimes in the summer months, whereas in the central regions one peak has been observed only in the summer season.

The situation in our case the total zooplankton had one main peak period in May ($3826 \pm 1052 \text{ ind.m}^{-3}$), in August ($1080 \pm 319 \text{ ind.m}^{-3}$) and in January ($797 \pm 153 \text{ ind.m}^{-3}$) were determined two small fluctuations.

It was notified that mesozooplankton abundance in the coastal waters was higher than in offshore waters in the Black Sea (Kovalev *et al.* 1999; Üstün *et al.* 2007). However, in the abundance of total mesozooplankton in this study, no significant differences were found between the stations. Similar situation was

observed by Ünal (2002). The reason for this might be the closeness between stations and/or fairly intensive vertical-exchange in central areas of the Black Sea and horizontal water-exchange between central and coastal areas (Kovalev 1991; Kovalev *et al.* 1999).

According to our results, the most dominant groups within the zooplankton community were *N. scintillans* (52.6%), Copepoda (21.4%) and Cladocera (13.3%) throughout the year. These are followed by Bivalvia, Appendicularia, Chaetognatha (*Sagitta* sp.), Cirripedia nauplii, Gastropoda and the Polychaeta larvae (Figure 8). *N. scintillans* reached a very high density in May.

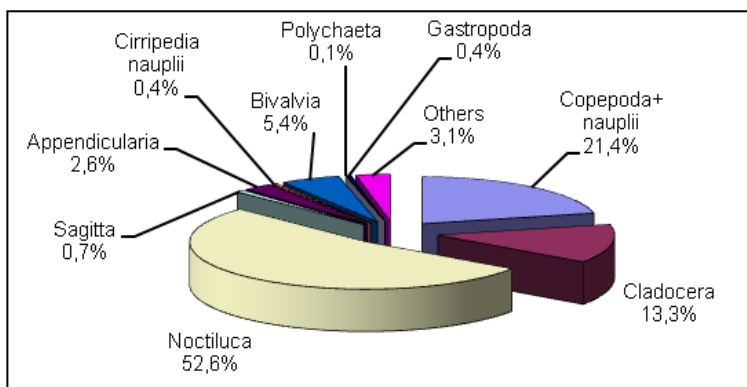


Figure 8. The proportions of zooplankton groups in annual total zooplankton (%)

In the study carried out in Sinop, the central Black Sea coast of Turkey, while *N. scintillans* was dominant with 43% (416 925 ind./m²) in May, following copepods were the second dominant group (42%, 172 981 ind./m²) in February in 1999, copepods were the dominant group (78%, 372 330 ind./m²) in March 2000 (Bat *et al.* 2007b).

Erkan and Gücü (2000) indicated that the zooplankton of the southeast Black Sea was dominated by the small organisms, such as *Noctiluca scintillans*, *Oithona similis*, young stages of *Pseudocalanus elongatus*, etc. Their results showed that the zooplankton in the Southeast Black Sea were dominated by small species and the most important species in the small zooplankton is *Noctiluca scintillans* due to its high abundance. Kovalev *et al.* (1998) and Shiganova *et al.* (1998) also observed that the abundance of *Noctiluca scintillans* increased in the Black Sea in recent years. Our results are similar to that of other studies carried out in the Black Sea.

Generally, taking into consideration of the monthly abundance distribution of the zooplankton groups, it can be seen that copepods were dominant during the major part of the year (between October and March); *N. scintillans* in April,

May and June; and cladocerans in July, August and September. The highest density of copepods was $551 \pm 152 \text{ ind.m}^{-3}$ in March ($27547 \pm 7612 \text{ ind.m}^{-2}$) and the lowest $61 \pm 15 \text{ ind.m}^{-3}$ in May ($3053 \pm 758 \text{ ind.m}^{-2}$). Copepoda was the most stable group with regard to monthly changes. Üstün *et al.* (2007) determined copepods were dominant group ($172\ 200 \text{ ind.m}^{-2}$) in 2003 in the annual abundance distribution of zooplankton. As for 2004, Noctiluca was indicated as dominant group ($172\ 000 \text{ ind.m}^{-2}$). Satılmış (2005) has found the quantity of copepods as at two different stations, which he specified as open sea and inner harbour of Sinop, $267800 \text{ ind.m}^{-2}$ and $491900 \text{ ind.m}^{-2}$, respectively.

As Cladocera emerge in the warmer months, its highest density was assessed in August (680 ind.m^{-3}) and then its abundance sharply decreased and disappeared in December, January and February. Within the year, there were two peaks which belong to two different species of Cladocera (predominantly *Penilia avirostris*).

The highest density of *N. scintillans* was observed in May ($3753 \pm 1027 \text{ ind.m}^{-3}$) and its lowest in March ($5 \pm 2 \text{ ind.m}^{-3}$). Unlike the other groups, *N. scintillans* reached very high density in May and thus, made a peak in this month. In contrast to this, sudden decrease was observed in the other groups in this month. Üstün *et al.* (2007) also pointed out that at the time when *N. scintillans* made a peak, there was an extreme decrease in the zooplankton abundance. The same situation was observed by Ünal (2002).

In 1993-1994 in Trabzon coast, Feyzioğlu (1996) ascertained that *N. scintillans* abundance was $3.84 \times 10^6 \text{ ind.m}^{-3}$ in March 1993 and $4.8 \times 10^6 \text{ ind.m}^{-3}$ in December 1993. During the sampling period, three peaks were observed by Feyzioğlu and Sivri (2003). The highest concentration of *N. scintillans* were observed as 99000 ind.m^{-3} in February 2000, 90000 ind.m^{-3} in June 1999 and 80500 ind.m^{-3} in September 1999. The plankton samples were taken from water column between the depth of 150 m and surface.

Consequently, both cell abundance and peak number of *N. scintillans* showed a big decrease according to previous years and it can be concluded that *N. scintillans* is not capable of making blooms in the southeastern Black Sea in recent years.

Our total zooplankton abundance changed from 233 to 3826 ind.m^{-2} in October 2007-September 2008 in the coast of Trabzon. The average zooplankton abundance was assessed as $1116 \pm 282 \text{ ind.m}^{-3}$. In order to make easier comparison, the previous and the present studies are shown in Table 3.

Table 3. Comparison of major taxa values of the present study with previous years in Sevastopol Bay and inshore station of Sinop and Trabzon region per year on average (ind. m⁻³)

	Gubanova <i>et al.</i> 2001		Ünal 2002	Bat <i>et al.</i> 2007b	Bat <i>et al.</i> 2005	Our result				
	Sevastopol Bay					Sinop Region			Trabzon Region	
	1976	1979-80	1989-90	1995-96	1999	2000	2002	2003	2004	2007-08
Total copepoda	6232	8932	540	361	568		274	1012	535	238 (11921 ind.m ⁻²)
<i>Copepoda nauplii</i>	299	540	74	71	48		30	102	40	
<i>Noctiluca scintillans</i>	1065	5067	1623	364	837		281	234	666	587 (29366 ind.m ⁻²)
Other Groups	2522	4913	1050	751	331		276	482	196	
Mesozooplankton (ind.m ⁻²)	108636	172656	19968	14196	68925		29065	79978	38590	
Mesozooplankton (ind.m ⁻³)	9053	14388	1664	1183	948		581	1599	771	
Total zoopla. (ind.m ⁻²)	121392	233460	39432	18564	128348	133544	91678	91678	71908	55989
Total zoopla. (ind.m ⁻³)	10116	19455	3286	1547	1785		1833	1833	1438	1116

Gubanova *et al.* (2001) determined in the years between 1976 and 1996, the amount of copepods at Sevastopol Bay, was 6232 ind.m⁻³ in 1976, 8932 ind.m⁻³ between 1979 and 1980, 540 ind.m⁻³ between 1989 and 1990 and 361 ind.m⁻³ between 1995 and 1996. According to Üstün *et al.* (2007) the total zooplankton changed from 4800-204 500 ind.m⁻² in 2003 to 13300-198900 ind.m⁻² in 2004 off Sinop. Bat *et al.* (2007b) reported that the total zooplankton abundance values were 43158 ind.m⁻² in 2002, 91678 ind.m⁻² (1834 ind.m⁻³) in 2003 and 71908 ind.m⁻² (1438 ind.m⁻³) in 2004. In the other study of Bat *et al.* (2007a), the total zooplankton abundance values were 128348 ind.m⁻² in 1999, 133544 ind.m⁻² in 2000 at Cape Sinop in the southern Black Sea.

In this study, monthly distribution of zooplankton abundance in the southern Black Sea (Trabzon coast) and group composition were investigated in there stations and compared to previous data from the same region. Monthly variations of zooplankton abundance had never been reported in the southern Black Sea (Trabzon coast) before. In this regard, the present study could give a basis for future studies in this region.

Acknowledgements

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Güneydoğu Karadeniz’de (Trabzon Kıyıları) zooplanktonun kalitatif ve kantitatif dağılımı

Özet

Çalışma, Trabzon-Yomra açıklarındaki üç farklı istasyonda zooplanktonun aylık kalitatif ve kantitatif değişimleri vertikal (50-0 m) olarak Ekim 2007-Eylül 2008 tarihleri arasında yapılmıştır. Toplamda 36 örnekleme yapılmıştır. Toplam zooplankton bolluğunun Mayıs ayında en yüksek değerine ulaştığı görülmüştür. Zooplankton topluluğu içerisinde en baskın grup % 54 ile *N. scintillans* (maksimum: 3752,80 birey m⁻³ - Mayıs) olmuştur. Onları %21 ile Copepoda (maksimum: 551 birey.m⁻³-Mart) ve %13 ile Cladocera (maksimum: 680 birey.m⁻³ - Ağustos) izlemiştir. Copepodlar örnekleme zamanlarında yıl boyunca bulunurken *N. scintillans* and Cladocera yılın sadece 2-3 aylık bölümünde baskın grup olmuşlardır. Yıllık ortalama zooplankton bolluk değeri 1116±282 birey m⁻³ (55989 birey.m⁻²) olarak hesaplanmıştır. Ayrıca temel fiziksel parametre olan sıcaklık değerleri farklı derinliklere göre tespit edilmiştir.

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