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Estuarine, Coastal and Shelf Science

Annual cycle of zooplankton abundance and species composition in Izmit Bay (the northeastern Marmara Sea)

Melek Isinibilir [a,*], Ahmet E. Kideys [b], Ahmet N. Tarkan [c], I. Noyan Yilmaz [d]

[a] Fisheries Faculty, Istanbul University, Laleli, 34470 Istanbul, Turkey
[b] Institute of Marine Science, Middle East Technical University, Erdemli, Turkey
[c] Fisheries Faculty, Mugla University, Mugla, Turkey
[d] Institute of Marine Sciences and Management, Istanbul University, Vefa, 34116 Istanbul, Turkey

ARTICLE INFO

ABSTRACT

The monthly abundance, biomass and taxonomic composition of zooplankton of Izmit Bay (the north-eastern Marmara Sea) were studied from October 2001 to September 2002. Most species within the zooplankton community displayed a clear pattern of succession throughout the year. Generally copepods and cladocerans were the most abundant groups, while the contribution of meroplankton increased at inner-most stations and dominated the zooplankton. Both species number (S) and diversity (H') were positively influenced by the increase in salinity of upper layers ($r = 0.30$ and $r = 0.31$, $p < 0.001$, respectively), while chlorophyll a was negatively affected ($r = -0.36$, $p < 0.001$). Even though $Noctiluca$ $scintillans$ had a significant seasonality ($F_{11,120} = 8.45$, $p < 0.001$, ANOVA), abundance was not related to fluctuations in temperature and only chlorophyll a was adversely correlated ($r = -0.35$, $p < 0.001$). In general, there are some minor differences in zooplankton assemblages of upper and lower layers. A comparison of the species composition and abundance of Izmit Bay with other Black Sea bays reveals a high similarity between them.

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1. Introduction

Coastal marine areas are of important ecological, economic and social interest (Calbet et al., 2001). They are extremely variable systems, where changes in the water circulation patterns, and fluctuations of land influences (e.g. rivers, sewage flow) induce high temporal variability on scales ranging from hours to seasons (Walsh, 1988). This variability may be reflected in the dynamics of the populations, particularly planktonic ones, thriving in coastal systems and can hide the underlying seasonal patterns of organisms' abundance and biomass (Calbet et al., 2001). Izmit Bay, as one of the most important coastal areas in the Marmara Sea, has been subjected to severe pollution problems (Okay et al., 1996; Morkoc et al., 2001a). Although industrial loads have been reduced by biological treatment and waste minimization from 1984 to 1995, the domestic wastes have doubled, due to the increasing population around the bay. The total discharge load into the bay in this period has therefore not changed significantly (Morkoc et al., 2001a). The August 1999 earthquake (magnitude 7.4 on the Richter scale), caused the destruction of waste-water discharge systems and caused a spill of refined petroleum and crude oil onto the sea surface from the refinery fire. After the earthquake, the increasing

organic and inorganic loads into the bay have stimulated dense phytoplankton blooms (Tas and Okus, 2004) which locally cause saturated DO concentrations in the eastern basin during autumn 1999 (Balkıs, 2003). Today the bay receives effluents from more than 300 industrial facilities, together with the untreated domestic waste waters from populated areas.

Izmit Bay, located on the NE Marmara Sea, is an elongated semi-enclosed bay with a length of 50 km, width varying between 2 and 10 km (Fig. 1). The Bay is composed of three sub-basins separated by shallow sills from each other. The eastern basin is relatively shallow (at about 30 m) whereas the central basin has two small depressions with depths of 160 and 200 m. The western basin deepens westward from 150 to 300 m and connects the bay to the Marmara Sea (Algan et al., 1999). Izmit Bay is oceanographically an extension of the Marmara Sea, having a permanent two-layered water system. The upper layer originates from less saline Black Sea waters (18.0–22.0), whereas the lower layer originates from the Mediterranean Sea waters which are more saline (37.5–38.5) (Unluata et al., 1990). Although a permanent stratification occurs at ∼25 m in the Marmara Sea (Besiktepe et al., 1994), it is highly variable in Izmit Bay (Oguz and Sur, 1986). The thickness of the upper layer changes seasonally from 9 m in spring to 18 m in autumn (Oguz and Sur, 1986; Algan et al., 1999). Inward currents are effective in spring and summer, related to the freshwater inflow changes at the Black Sea. This regime shifts in autumn and winter

* Corresponding author.
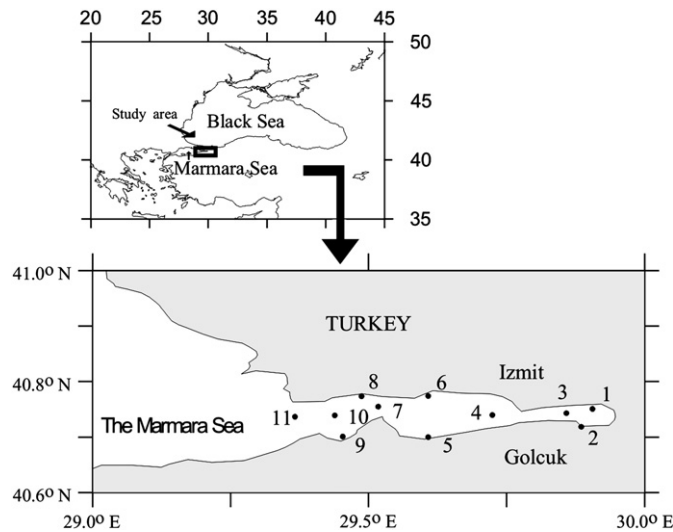 E-mail address: melekis@istanbul.edu.tr (M. Isinibilir).

Fig. 1. Positions of the sampling stations.

when there is an outward flow from the bay to the Marmara Sea (Oguz and Sur, 1986). Vertical mixing of the two layers is restricted and occurs at shallow depths. An intermediate layer of varying thickness develops throughout the year in the water column of the bay (Oguz and Sur, 1986).

Although there have been several studies on the pollution, physical and chemical characteristics of the bay (e.g. Okay et al., 1996; Morkoc et al., 2001a; Okay et al., 2001; Tolun et al., 2001; Balkıs, 2003; Pekey et al., 2004), there has only been one study about zooplankton structure by Tarkan et al. (2000) who examined the dominant zooplankton species of Izmit Bay. There are however no data on the annual zooplankton abundance, diversity and species composition.

The aim of the present study is to examine the zooplankton annual cycle in Izmit Bay, as shown by the seasonal evolution of zooplankton community structure, as well as to evaluate the influence of environmental parameters on them.

2. Material and methods

2.1. Sampling design and analysis of samples

Upper layer samples, characterizing Black Sea originated and locally-polluted Marmara waters were monthly collected at 11 stations in Izmit Bay (Fig. 1) from October 2001 to September 2002. Samples from the Mediterranean-originated lower layer were taken only from three stations (2, 4 and 10) from April 2002 to August 2002, during the presence of thermal stratification and haline stratification. The 11 sampling sites were categorized into three groups (eastern, middle and western parts). The eastern part of the bay is represented by stations 1, 2, 3; the middle part by 4, 5, 6; and the western part by 7, 8, 9, 10 and 11 (Fig. 1).

All samples were collected vertically during daytime, by a WP2 closing net (157 μm mesh, 0.5 m diameter) from the interface (18–20 m), to the surface and from the bottom to the interface for samples from the lower layers. The net was rinsed gently and samples were transferred into plastic containers, and fixed by addition of borax-buffered formaldehyde to a final concentration of 4%. Identification of specimens was carried out under a stereomicroscope using a Bogorov–Rass counting chamber. Quantitative analyses of common species were conducted from sub-samples taken by a 1 ml Stempel pipette (at least twice). Rare species were identified from the entire sample. Cladocerans and copepods were identified to species or genus level. All other taxa were identified to the lowest possible taxa.

Water temperature and salinity was measured by pIONeer 65 multi-probe, using the practical salinity scale. Chlorophyll a analyses were performed following the methodology of Nusch (1980).

2.2. Data analysis

The Shannon index of diversity (Shannon and Weaver, 1949) was used for the estimation of community diversity, while dominance was calculated according to Simpson (1949).

For multivariate analyses of community structure, a similarity matrix was constructed from $\log_e(x + 1)$ transformed zooplankton abundance data, using the Bray–Curtis coefficient of similarity and sample interrelations were mapped by non-metric multidimensional scaling (MDS) using PRIMER v5.2.4, according to Clarke (1993) and Clarke and Gorley (2001). Axes scores of MDS were accepted as the best descriptors of zooplankton community structure in two-dimensional space. The relationship between MDS axis scores and temperature was questioned by Pearson correlation, while partial correlations were used for salinity and chlorophyll a, in order to control the effects of temperature. Environmental data were transformed to natural logarithms prior to the analysis. One-way ANOVA was used to test the null hypotheses that zooplankton community did not significantly differ in relation to spatio-temporal patterns.

In order to seek similarities between upper and lower layer communities, a second MDS was constructed from simultaneously collected upper and lower layer zooplankton abundance data of stations 2, 4 and 10. These data were treated as in the aforementioned procedure and one-way ANOVA was utilized to see whether there was a significant difference among layers.

Spatio-temporal patterns in zooplankton community structure and physical (salinity) and biological (*Noctiluca*, chlorophyll a) data were investigated among stations and months by ANOVA. Prior to analysis of variance, biological and physical data were normalized by logarithmic transformations. Since an important fraction of data was not homogeneous after transformations, the probability for ANOVA was set at 0.01 to reduce type-I errors (Underwood, 1981).

3. Results

3.1. Hydrography

The two-layered stratification is evident from the temperature and salinity profiles (Fig. 2). The seasonality is clear for temperature ($F_{11,120} = 429.94$, $p < 0.001$, ANOVA), chlorophyll a ($F_{11,120} = 9.07$, $p < 0.001$, ANOVA) and salinity ($F_{11,118} = 5.01$, $p < 0.001$, ANOVA) (Fig. 3). However, only chlorophyll a varied significantly among stations ($F_{10,119} = 6.40$, $p < 0.001$, ANOVA). The temperature ranged
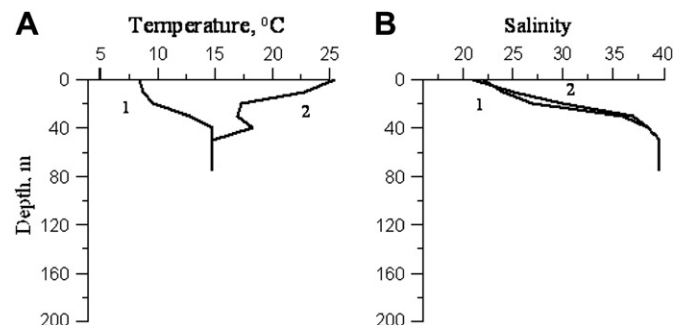

Fig. 2. The profiles of temperature and salinity, typical for winter (1) and summer (2) in Izmit Bay.
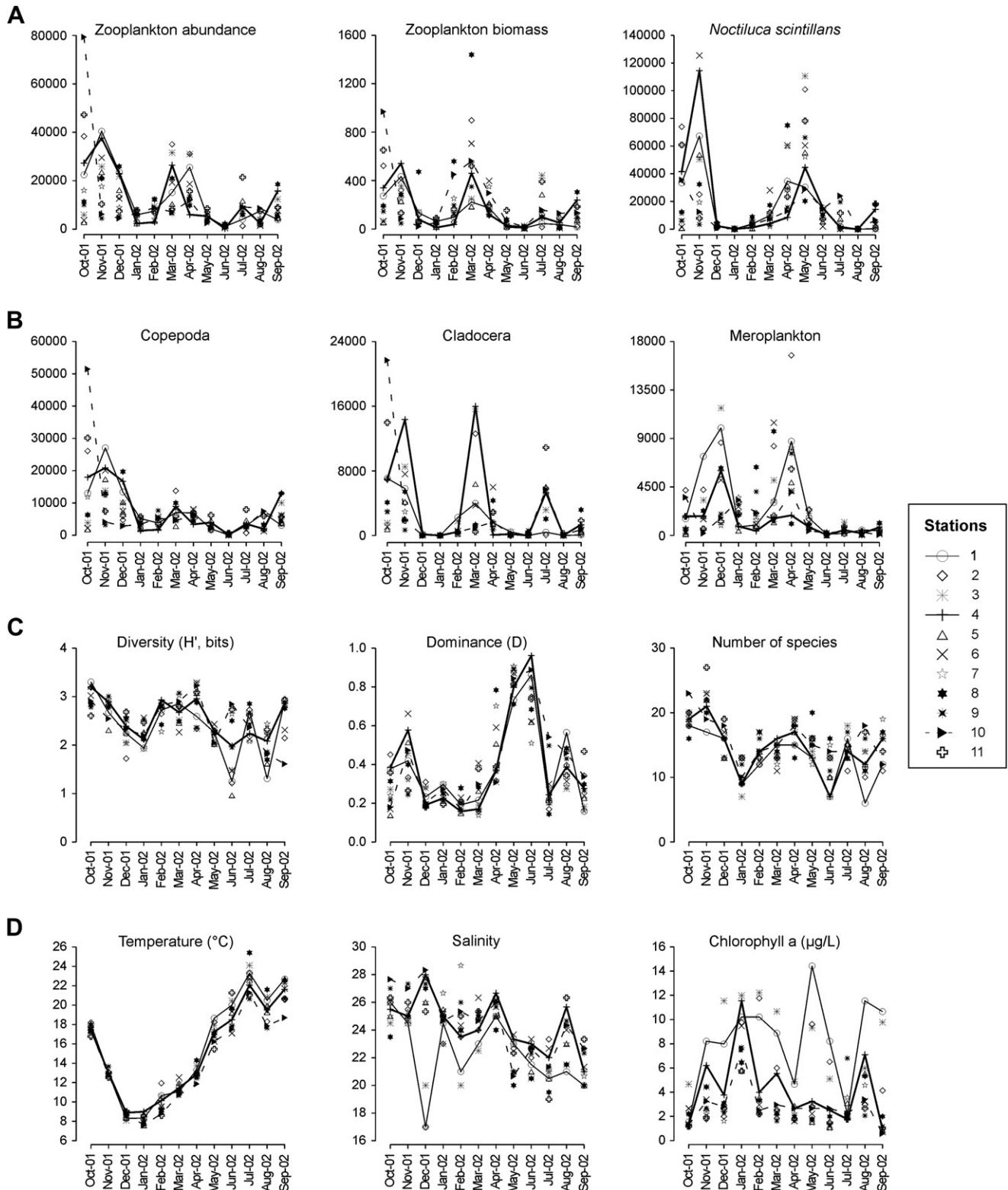
Fig. 3. Fluctuations in (A) zooplankton abundance (ind. m^{-3}), biomass (mg m^{-3}) and *Noctiluca scintillans*; (B) copepoda, cladocera and meroplankton abundance (ind. m^{-3}); (C) zooplankton diversity; (D) environmental parameters.

from 7.6 °C (January 2002) to 21.6 °C (July 2002). The salinity of the upper layer decreased in summer due to the arrival of the SW Black Sea shelf waters, while in winter the eastern part of the bay had lower salinity due to precipitation. The minimum salinity (17.0 at stations 1 and 2) was observed in December 2001. In February

2002, the upper layer salinity increased to 28.7 (Station 7). A negative correlation was observed between temperature and salinity ($r = -0.44$, $p < 0.001$), as a result of apparent seasonal patterns in fluctuations of salinity. Chlorophyll *a* was high at the inner-most section (stations 1, 2, 3 and 4); while concentrations were relatively

lower in the middle and western parts of the bay (Fig. 4). The distribution of chlorophyll *a* was highly variable, but still had significant spatio-temporal patterns and was weakly correlated with temperature ($r = -0.32$, $p < 0.001$).

3.2. Zooplankton species assemblages and diversity

Zooplankton abundance and biomass showed a seasonal distribution in Izmit Bay (Fig. 4). The total zooplankton abundance (excluding the dinoflagellate *Noctiluca scintillans*) was characterized by two peaks, autumn and spring (Fig. 3). The highest zooplankton abundance was encountered at station 10 in October 2001 (79,332 ind. m^{-3}), particularly due to high *Penilia avirostris* and *Oithona nana* abundance (18,650 ind. m^{-3} and 19,261 ind. m^{-3}, respectively). The zooplankton biomass, on the other hand, was the highest at station 8 in March 2002, due to *Calanus euxinus* (Fig. 3). Most of the zooplankton groups exhibited clear seasonality in Izmit

Bay. Generally copepods and cladocerans were the most abundant groups, while contribution of meroplankton increased at innermost sections and dominated zooplankton (e.g. station 2, April 2002). *Acartia clausi* was present all year, reaching higher densities in early winter (Fig. 5), while *Centropages ponticus* and *Calanus euxinus* were the most important contributors to the copepod community during winter and spring. *Oithona nana*, *Euterpina acutifrons* and *Paracalanus parvus* were abundant in autumn. *Pleopis polyphemoides* was encountered in autumn and spring, while fine particle filter feeders, i.e. *Penilia avirostris* and *Oikopleura dioica*, dominated the zooplankton community in late summer and autumn. Bivalve larvae reached high concentrations in winter and spring particularly at inner regions.

Species number (S) and diversity (H') varied significantly through the year ($F_{11,120} = 19.71$ and $F_{11,120} = 13.06$, $p < 0.001$, respectively, ANOVA) and dropped to their lowest values in June, particularly at stations located at eastern part of the bay, while
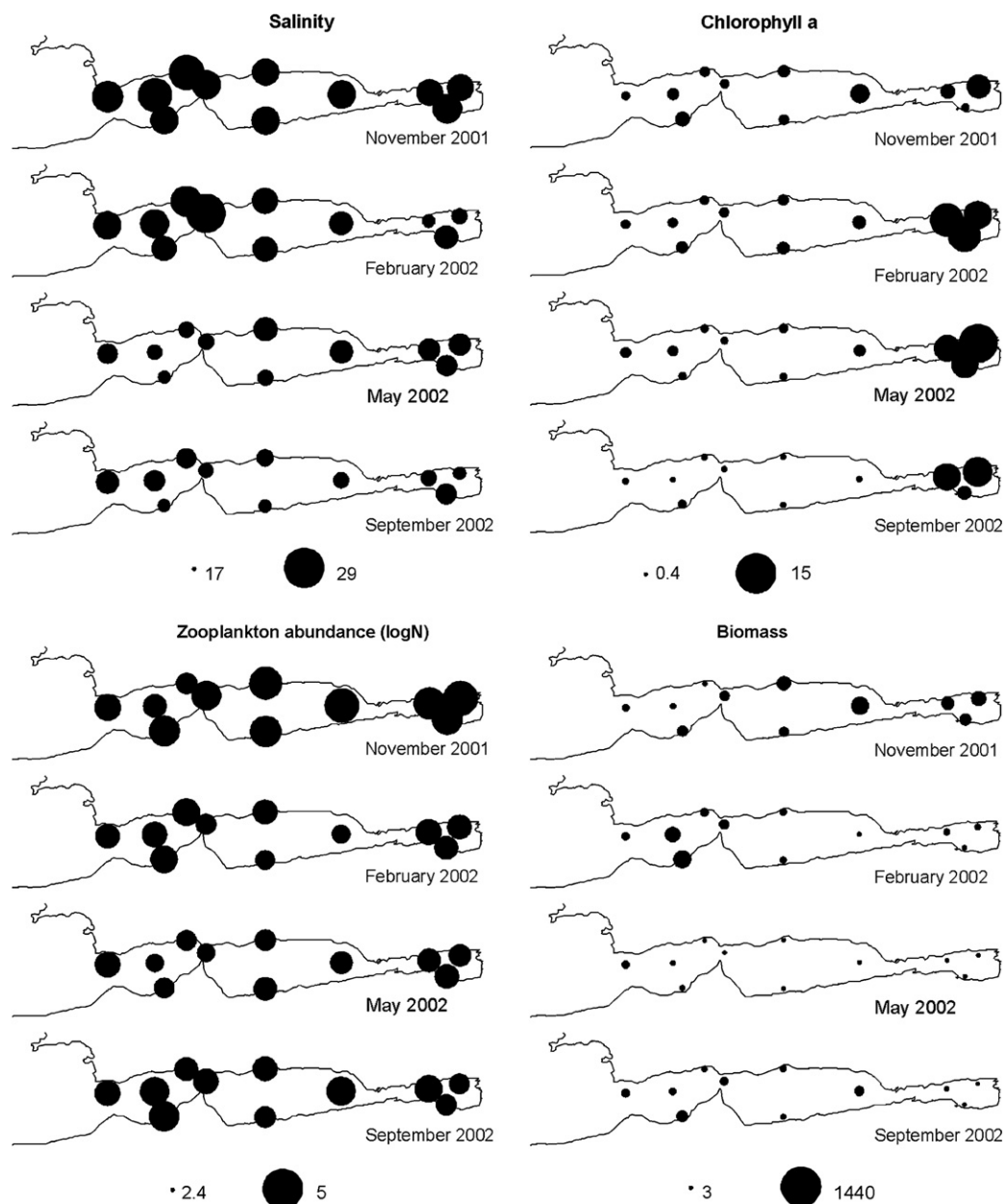

Fig. 4. Spatial distribution of salinity, chlorophyll *a* (μg. L^{-1}), zooplankton abundance (log ind. m^{-3}) and zooplankton biomass (mg m^{-3}) in upper layer of Izmit Bay. Figure legends indicate minimum and maximum values in the 12-month data.
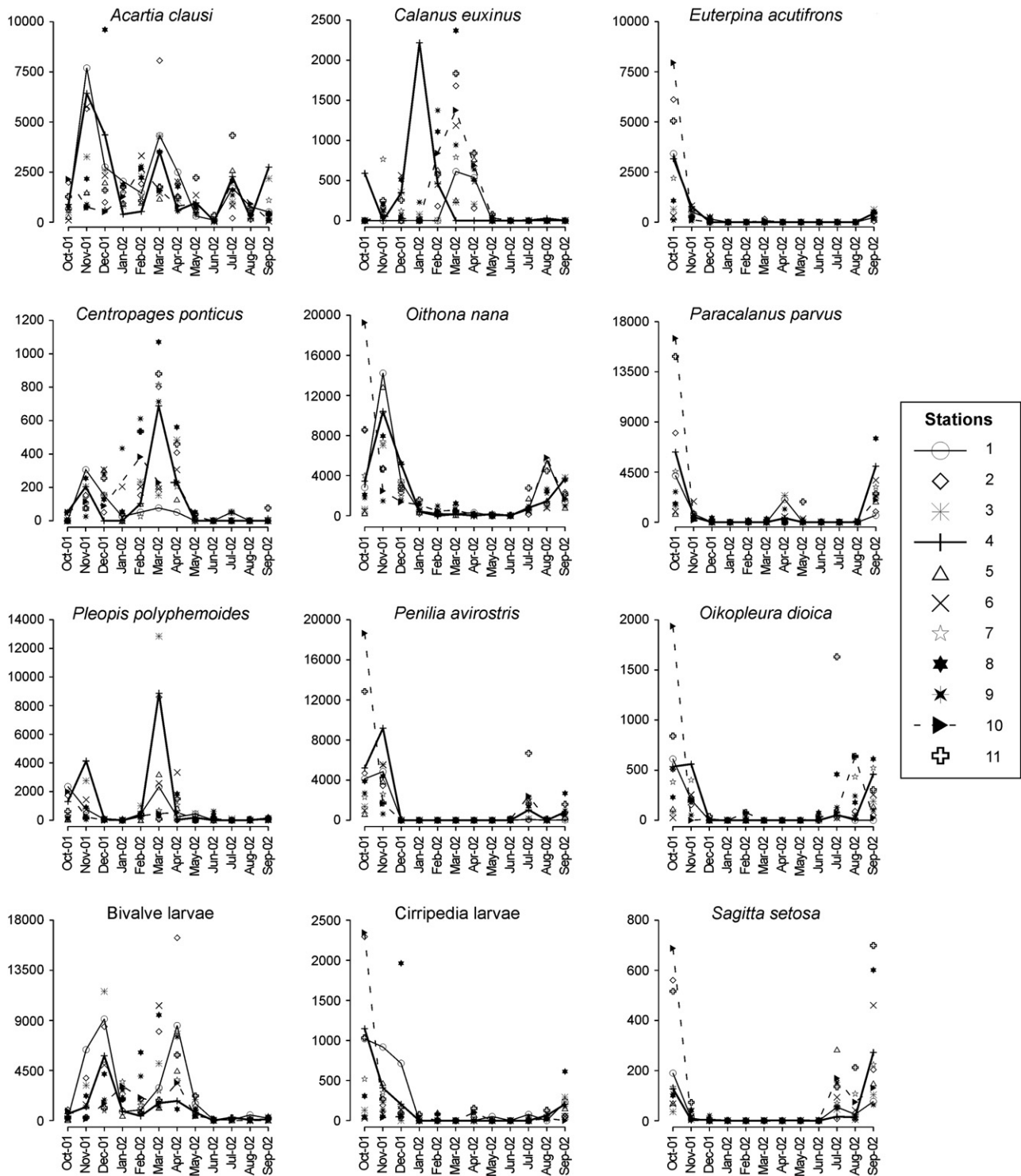
Fig. 5. Fluctuations in abundance of major zooplankton species and groups in the upper layer.

dominance in the zooplankton community attained the highest values. This decrease in diversity is due to the numerical dominance of *Favella* sp. (Ciliata, Tintinnina), Polychaeta larvae and copepodites. In addition a phytoplankton bloom in January, as designated by high chlorophyll *a* concentration, also caused a remarkable decrease in *S* and *H′*. Both *S* and *H′* were positively influenced by the increase in salinity ($r = 0.30$ and $r = 0.31$, $p < 0.001$, respectively), while chlorophyll *a* negatively affected *S* ($r = -0.36$, $p < 0.001$).

3.3. *Noctiluca scintillans*

The heterotrophic dinoflagellate *Noctiluca scintillans*, as a major component of net samples in Izmit Bay, followed a rather regular trend throughout the year, with highest values in November 2001 (1.26×10^5 ind. m^{-3}) and May 2002 (1.11×10^5 ind. m^{-3}). In November, middle parts of the bay had higher *Noctiluca* abundance, while in May innermost sections had higher values. *N. scintillans* density dropped sharply to minimum levels following November

peak, and abundances were very low from December to February. The species was not encountered in August sampling. Even though the species had a significant seasonality ($F_{11,120} = 8.45$, $p < 0.001$, ANOVA), abundance was not related to fluctuations in temperature and only chlorophyll a was inversely correlated ($r = -0.35$, $p < 0.001$).

3.4. Zooplankton community structure

The zooplankton community of Izmit Bay had high seasonality, particularly along the first axis of MDS ordination (Fig. 6, $F_{11,120} = 117.52$, $p < 0.001$). Seasonal patterns were also very strong along the second axis ($F_{11,120} = 71.81$, $p < 0.001$), while no spatial differences were observed along both axis. Winter community was characterized by high abundance of *Calanus euxinus* and bivalve larvae (Group A). June samples were clearly separated on the ordination plane and displayed the highest within month variation (Group B). This pattern is due to the differences in species composition in eastern, western and middle parts of the bay (Fig. 6), particularly due to the high abundance of *Favella* sp., *Pleopis polyphemoides* and Rotifera. Summer communities were gathered in Group C and samples were dominated by *Penilia avirostris*, *Oithona nana* and *Paracalanus parvus*. November samples displayed a more homogeneous community structure, as transition period from summer to winter communities (Group D). The first axis of MDS was significantly correlated with temperature ($r = -0.70$, $p < 0.001$). On the other hand the second axis was weakly associated with salinity ($r = 0.26$, $p = 0.003$) and chlorophyll a ($r = -0.27$, $p = 0.003$).

3.5. Comparison of upper and lower layers

Limited samplings performed at the lower layer showed that the upper layer generally had higher zooplankton abundance than the lower layer (Table 1). In the upper layer, maximum average abundance was 8714 ± 12738 ind. m^{-3}, while the respective value was 4039 ± 7933 ind. m^{-3} in the lower layer. Two-way ANOVA showed significant differences of zooplankton abundance ($F = 5.13$, 2 d.f., $p = 0.013$) and number of species ($F = 7.83$, 2 d.f., $p = 0.002$) between layers. Both layers were generally dominated by Copepoda and Cladocera in the western part, while bivalve larvae were higher at the lower layer in eastern parts. There are some minor differences in zooplankton assemblages of upper and lower layers, e.g. the occurrence of *Oncaea* sp. MDS ordination of combined data of upper and lower layers showed that the highest variation in data (Axis 1) is controlled by seasonal patterns ($F_{1,28} = 8.45$, $p = 0.007$, ANOVA) while samples were clearly discriminated according to

their strata along the second axis ($F_{4,25} = 9.25$, $p < 0.001$, ANOVA) (Fig. 7). *Noctiluca* abundance also significantly varied among layers ($F_{1,28} = 8.17$, $p = 0.008$, ANOVA).

4. Discussion

The present study provides information on the neritic area of Izmit Bay by describing the main zooplankton species and their seasonality. In the study, the most widely distributed zooplankton species were also the most abundant ones, such as *Paracalanus parvus*, *Acartia clausi*, *Oithona nana*, *Calanus euxinus*, *Euterpina acutifrons*, *Penilia avirostris*, *Evadne tergestina*, *Pleopis polyphemoides* and bivalve larvae. These species are similar to those reported for the Marmara Sea (Tarkan and Erguven, 1988; Unal et al., 2000; Yuksek et al., 2002; Yilmaz et al., 2005).

As a highly stratified basin, zooplankton abundance was higher in the upper layer than the lower layer in Izmit Bay. The same tendency for zooplankton abundance was also observed in Istanbul Strait (Tarkan et al., 2005) and in open parts of the Marmara Sea (Unal et al., 2000). The strong stratification at the basin is known to limit diurnal vertical migration pattern of zooplankton and its main biomass is concentrated at the upper layer (Mutlu, 2005). On the contrary, current data indicated similarities among upper and lower layers with some differences in species assemblages. The reason for this pattern should be attributed to the relatively closed and shallow structure of the Izmit Bay. The upper layer was characterized by significantly higher values of total zooplankton abundance and biomass.

The coastal areas of Izmit Bay have been greatly affected by anthropogenic influences during the last decades (Morkoc et al., 2001b). The increases in the nutrient and pollutant inputs have induced changes in both hydrological and hydro-chemical regimes, resulting in intense eutrophication of the area (Morkoc et al., 2001b; Okay et al., 2001). The magnitude of eutrophication increased from outer to inner parts and the inner-most sections of the bay (eastern part) had higher zooplankton abundance due to the enrichment of the region by terrestrial and anthropogenic influxes through the small freshwater inflow. The effects of eutrophication have also been observed on a temporal scale and a clear increase in zooplankton abundance in the bay between 1975 (maximum 1776 ind. m^{-3}) to 2002 (maximum 79,345 ind. m^{-3}) could be taken as a negative aspect of the artificial eutrophication of the region.

Yilmaz et al. (2005) reported two zooplankton abundance maxima for the NE Marmara Sea: one in autumn (September–October 2001) and a second peak in summer (July 2002). During the study in Izmit Bay, an autumn maximum was detected at station 10, but a second peak was observed in spring (March–April) at almost all stations located in eastern part of the bay. The autumn maximum was related to the abundance of cladocerans and copepods, while the spring one is almost exclusively due to copepods. Autumn and spring maxima have also been reported in the Sevastopol Bay (Ukraine) and Galata Cape (Bulgaria) (Hubareva et al., 2004; Siokou-Frangou et al., 2004). The spring maximum could be associated with the phytoplankton peak; during the study period, chlorophyll a reached highest values in January–February 2002. As for the spring and autumn peak, a relationship with elevated chlorophyll a values could be explained at almost all stations. The zooplankton community structure is comparable to other regions of the Marmara Sea. The only significant difference is the high abundance of *Calanus euxinus* and its contribution to the winter community.

A similar trend to total zooplankton abundance was observed in *Noctiluca scintillans* distribution. Two peaks in abundance have been reported in spring (April–June) and November for *N. scintillans* in the Marmara Sea (Yilmaz et al., 2005). This species is known
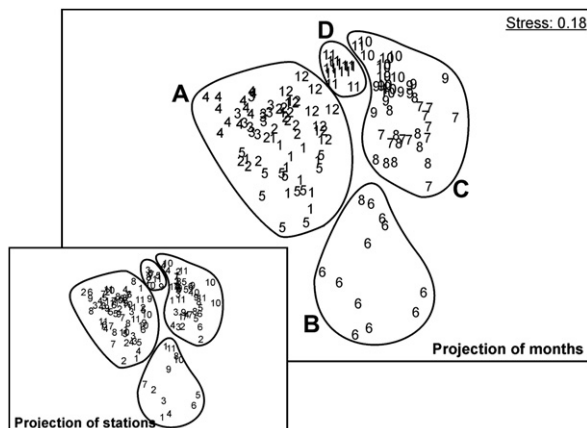

Fig. 6. MDS ordination of upper layer samples.

Table 1
The regional mean abundance (ind. m^{-3}) of dominant mesozooplankton taxa in the upper and lower layers of Izmit Bay (in stations 2, 4, 10) from April to August

	Upper layer			Lower layer		
	East	Middle	West	East	Middle	West
	2	4	10	2	4	10
Copepoda	2245 ± 190	2604 ± 265	3782 ± 332	971 ± 16	497 ± 23	1720 ± 120
Acartia clausi	464 ± 519	813 ± 889	948 ± 691	314 ± 470	143 ± 214	250 ± 315
Calanus euxinus	31 ± 68	97 ± 202	144 ± 304	0	31 ± 37	281 ± 409
Centropages ponticus	82 ± 182	46 ± 103	51 ± 100	8 ± 16	15 ± 21	0
Oithona nana	268 ± 530	592 ± 653	1315 ± 2511	13 ± 28	87 ± 194	71 ± 146
Oithona smiles	46 ± 63	25 ± 57	56 ± 125	6 ± 14	15 ± 28	41 ± 59
Paracalanus parvus	20 ± 46	71 ± 160	61 ± 91	0	5 ± 11	57 ± 115
Pseudocalanus elongatus	566 ± 1265	71 ± 160	270 ± 590	31 ± 62	3 ± 6	290 ± 608
Oncaea media	0	0	0	64 ± 142	61 ± 110	87 ± 194
Cladocera	318 ± 72	1121 ± 446	1554 ± 347	73 ± 1	84 ± 1	92 ± 2
Evadne tergestina	10 ± 23	1083 ± 2149	821 ± 1643	13 ± 28	10 ± 23	15 ± 34
Penilia avirostris	8 ± 11	204 ± 456	510 ± 1055	0	10 ± 23	6 ± 13
Pleopis polyphemoides	20 ± 46	41 ± 78	158 ± 215	57 ± 128	38 ± 79	71 ± 121
Cirriped larvae	25 ± 44	13 ± 28	32 ± 48	0	3 ± 6	0
Appendicularia	23 ± 39	13 ± 22	148 ± 275	0	10 ± 14	48 ± 88
Chaetognatha	2 ± 3	6 ± 8	49 ± 74	0	5 ± 9	13 ± 25
Polychaete larvae	49 ± 48	50 ± 39	129 ± 230	13 ± 17	11 ± 11	56 ± 85
Bivalve larvae	3638 ± 7158	601 ± 717	851 ± 1426	1207 ± 2220	125 ± 167	145 ± 161
Total zooplankton	8714 ± 12738	4710 ± 3507	6662 ± 4698	4039 ± 7933	765 ± 519	2111 ± 2130

to increase its abundance significantly in semi-closed and eutrophic bays of the basin (Yilmaz et al., unpublished). Although the aforementioned studies indicate that the November increase is a minimum of ~10-fold weaker than the spring one, in the current study both periods were characterized by very similar abundances. This pattern should be associated with a continuous production at the region, promoting *Noctiluca* growth in favorable conditions. This high biomass of *Noctiluca* significantly affected the zooplankton community structure and the partial correlation between first axis score of MDS and *Noctiluca* abundance (controlling for the effect of temperature) pointed out a significant negative correlation ($r = -0.40$, $p < 0.001$). Recent work has suggested that *N. scintillans*, competing for the same food resources with many other zooplankters, significantly affects the zooplankton community structure and abundance in the Marmara Sea (Yilmaz et al., 2005). In contrary to this work, however, descriptors of zooplankton diversity were generally positively correlated with the increase in *Noctiluca* abundance in Izmit Bay. This peculiar trend should be taken as an effect of eutrophication in the region, and the factors increasing *Noctiluca* abundance also caused an increase in zooplankton abundance and diversity.

The comparison between the Black Sea and the Aegean Sea coastal ecosystems reveals both differences and similarities in

zooplankton abundance (Kovalev et al., 2001). Studies from other areas of Marmara Sea, Black Sea and Mediterranean Sea (Ogdul and Erguven, 1992; Siokou-Frangou, 1996; Yuksek et al., 2002; Kovalev et al., 2003; Isinibilir and Tarkan, 2004; Siokou-Frangou et al., 2004; Yilmaz et al., 2005) showed that copepods and cladoceras are dominant groups (excluding *Noctiluca scintillans*) in spring, summer and autumn. In the Mediterranean Sea which shows characteristics of oligotrophic waters, higher diversity and lower abundance of zooplankton (Siokou-Frangou, 1996) were recorded than the findings of Izmit Bay. The Black Sea is characterized by low salinity, varying between 18 and 24, resulting in the dominance of euryhaline marine species and the important presence of brackish-water species (Zaitsev, 1992). According to the distribution of water masses, the structure of the zooplankton community in the upper water of Izmit Bay has been established by species originated from Black Sea. A comparison of the species composition of Izmit Bay with Black Sea bays reveals a high similarity between them. The abundance and biomass of zooplankton in the Izmit Bay is, however, higher than the values in other areas of the Black Sea (Gubanova et al., 2001; Hubareva et al., 2004; Bat et al., 2007; Ustun et al., 2007), which is probably due to the stratified structure and lack of strong current system as well as the high nutrient input. This indicates that there are favorable conditions for zooplankton populations in Izmit Bay.

Acartia clausi, a eurythermic and euryhaline copepod, is widely distributed in temperate and warm waters of the Atlantic and Pacific oceans and in the Black Sea and the Mediterranean, where it reproduces all year round (Gubanova et al., 2001). The species has a high tolerance to pollution and it usually dominates zooplankton in polluted areas. In summer, *A. clausi* is generally the only copepod species observed in polluted waters (Lakkis, 1974; Gubanova et al., 2001). The results of the present work also support these findings and indicate a dominance and year-round occurrence of *A. clausi* in the region which reflects the eutrophic characteristics of the area.

The copepod *Oncaea media* is a typical Mediterranean species and was found in Marmara Sea (Unal et al., 2000). *Oncaea media* was found only in the lower layer of Izmit Bay. This indicates that the upper layer water is formed by the Black Sea water with lower salinity which is unsuitable for *O. media* because of the low salinity.

The method used for sampling zooplankton was not very suitable for micro-zooplankton (Cilliata). However, in our samples,
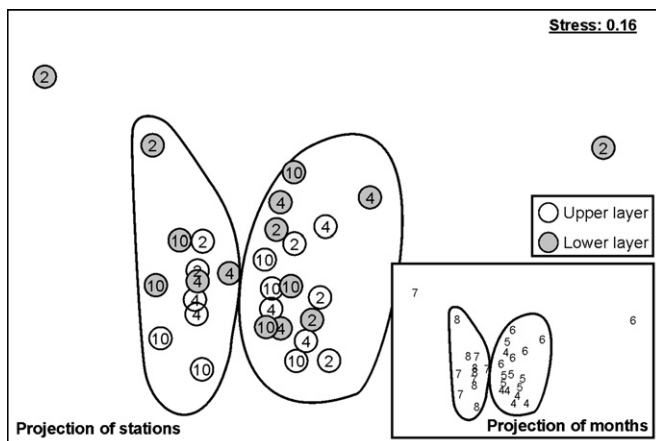
Fig. 7. MDS ordination of combined data of upper and lower layer samples.

high numbers of *Favella* sp. (Ciliata) were found in the upper water of Izmit Bay in late spring–early summer (especially in July). There are no data on the tintinnid community in Izmit Bay. Balkıs (2004) reported a list of tintinnid species and their abundance in Buyukcekmece Bay in the Marmara Sea. The percentage distribution of tintinnids revealed that the highest numbers of tintinnid species were found in June and November. Although the peak of *Favella* sp. in Izmit Bay was in the same period in July we did not find it in November. Meso-zooplankton feeds on tintinnids (Levinsen and Nielsen, 2002) and their lowest abundance was found in July. Since tintinnid species structure were not measured in this study, we do not know the exact effect on the meso-zooplankton, but it would be interesting to study the relationship between tintinnids and meso-zooplankton in Izmit Bay.

Eutrophication can have an indirect effect on zooplankton species diversity through its impact on the phytoplankton (Shiganova et al., 1998). With increasing phytoplankton biomass, the abundance of *Noctiluca scintillans* and herbivorous zooplankton species increase (Shiganova et al., 1998). In Izmit Bay, decreasing nutrients from the eastern to western part (Aktan et al., 2005) may have caused an increase in species diversity of zooplankton. High densities due to increase of one species generally corresponded with low species diversity, thus explaining the negative correlation between species diversity and zooplankton abundance. Diversity values were lower in the eastern and middle parts, which are affected extensively from industrial and domestic inputs. This result shows that increasing productivity cause decreases in zooplankton diversity.

Gelatinous zooplankton in the Black Sea can influence the zooplankton community substantially (Kideys et al., 2000; Kideys and Romanova, 2001). The same effect has been observed in the Marmara Sea (Isinibilir et al., 2004). Gelatinous zooplankton, especially *Mnemiopsis leidyi*, are known to feed voraciously on zooplankton (Tsikhon-Lukashina et al., 1991; Finenko et al., 2001). In Izmit Bay, the invader species *Mnemiopsis leidyi* and the resident *Aurelia aurita* and *Pleurobrachia pileus* had high abundances during 2001–2002 and the highest population of gelatinous zooplankton occurred in summer and at the end of autumn (Isinibilir, 2007). This may suggest that gelatinous zooplankton may be an important force in initiating winter and summer decline in zooplankton in Izmit Bay.

In conclusion, the zooplankton abundance is primarily controlled by fluctuations in physical environment, particularly temperature, which causes high seasonality among samples. Due to pollution and eutrophication the copepod *Acartia clausi* and the dinoflagellate *Noctiluca scintillans* were favored, while rare species became extinct. It is clear that for a better understanding of the ecosystem of Izmit Bay, long-term monitoring data on the important biological components and on the quality and quantity of zooplankton is essential.

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