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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

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ABSTRACT

The monthly abundance, biomass and taxonomic composition of zooplankton of Izmit Bay (the northeastern 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.

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).

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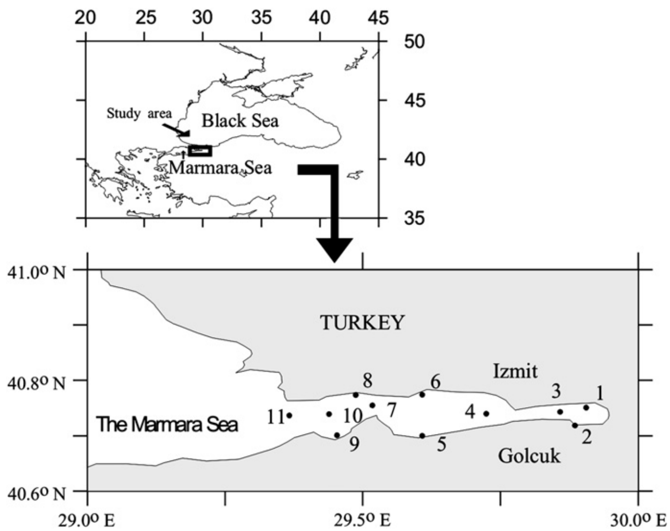

Fig. 1. Positions of the sampling stations.

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 stereo-microscope 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

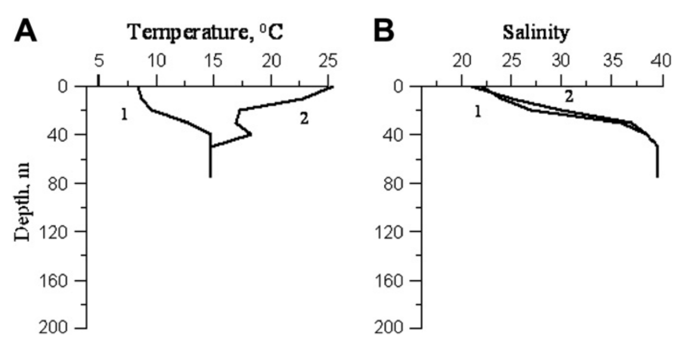

Fig. 2. The profiles of temperature and salinity, typical for winter (1) and summer (2) in Izmit Bay.