COMU J Mar Sci Fish 2025 8(1): 97-102
https://doi.org/10.46384/jmsf.1719494
e-ISSN: 2651-5326

COMU Journal of Marine Sciences and Fisheries

Journal Home-Page: http://jmsf.dergi.comu.edu.tr Online Submission: http://dergipark.org.tr/jmsf

RESEARCH ARTICLE

Zooplankton Composition in the Southwestern Sea of Marmara During the Summer Season

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Received: 13.06.2025 /Accepted: 07.07.2025 / Published online: 14.07.2025

Keywords:

Mesozooplankton
Diversity indices
Abundance
Erdek Bay

Abstract: The Sea of Marmara (SoM) is a highly sensitive semi-enclosed marine ecosystem that has been undergoing considerable ecological changes in the recent decades. This study aimed to evaluate the summer zooplankton community structure via vertical hauls at 0-20 m depth in Erdek Bay, located in the southwestern part of the SoM, during two consecutive years, 2019 and 2020. The results revealed marked year-to-year shifts. In 2020, total zooplankton abundance declined markedly compared to 2019, primarily due to a sharp decrease in the abundance of *Penilia avirostris*, which was dominant in the community during 2019. Despite the higher abundance observed in 2019, diversity indices were lower, indicating that the community structure was largely shaped by the dominance of a single species. In contrast, unlike the Cladocera group, Copepoda abundance increased in 2020 compared to 2019. As the most recent data for this region date back to the early 2010s, this research provides an updated contribution to the understanding of summer zooplankton composition in Erdek Bay. The findings highlight the necessity for long-term zooplankton monitoring with high temporal resolution to better understand zooplankton dynamics in response to environmental changes in the southwestern part of the Sea of Marmara.

Anahtar kelimeler:

Mesozooplankton
Çeşitlilik indeksleri
Bolluk
Erdek Körfezi

Marmara Denizi'nin Güneybatısında Yaz Dönemi Zooplankton Kompozisyonu

Öz: Marmara Denizi, son yıllarda önemli ekolojik değişimlerin yaşandığı, oldukça hassas yarı kapalı bir denizel ekosistemdir. Bu çalışma, Marmara Denizi'nin güneybatısında yer alan Erdek Körfezi'nde yaz dönemi zooplankton topluluk yapısını, iki farklı yıl olan 2019 ve 2020'de 0-20 m derinlikte yapılan dikey çekimler ile değerlendirmeyi amaçlamıştır. Elde edilen sonuçlar yıllar arası belirgin farklılıkları ortaya koymuştur. 2020 yılında, zooplanktonun toplam bolluğu 2019 yılına kıyasla önemli ölçüde azalmıştır. Bu düşüşün başlıca nedeni, 2019 yılında toplulukta baskın olan *Penilia avirostris* türünün bolluğundaki keskin azalmadır. 2019 yılında yüksek bolluk gözlemlenmesine rağmen, çeşitlilik indekslerinin daha düşük olması, topluluk yapısının büyük ölçüde tek bir türün baskınlığıyla şekillendiğini göstermektedir. Buna karşılık, Cladocera grubunun aksine, Copepoda bolluğu 2020 yılında 2019'a göre artış göstermiştir. Bölgeye ait en güncel veriler 2010'lu yılların başına dayandığından, bu çalışma Erdek Körfezi'ndeki yaz dönemi zooplankton bileşimine ilişkin güncel bir katkı sunmaktadır. Elde edilen bulgular, Marmara Denizi'nin güneybatı kesiminde çevresel değişimlere bağlı olarak zooplankton dinamiklerini daha iyi anlayabilmek için yüksek zaman çözünürlüğüne sahip uzun dönemli zooplankton izleme çalışmalarının gerekliliğini vurgulamaktadır.

Introduction

Zooplankton occupy a central position in marine food webs. Through their feeding on phytoplankton, they modulate primary production dynamics while simultaneously serving as the key prey for planktivorous fishes such as anchovy and sardine within the upper pelagic system. This dual role positions zooplankton as trophic intermediaries that actively mediate the flow of energy through pelagic ecosystems (Steinberg and Landry, 2017). The short generation times of zooplankton and their diverse reproductive strategies enable rapid responses to both favourable and adverse environmental changes. Consequently, they serve as sensitive indicators in marine ecosystem monitoring (Shiganova, 2005; Büyükateş and İnanmaz, 2007; İşinibilir *et al.*, 2008; Bedikoğlu *et al.*, 2020). Shifts in zooplankton abundance and community composition provide key signals of ecosystem change, with cascading effects on all biological components of the

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How to cite this article: Bedikoğlu, D., Jerinić, S. & Demirel, N (2025). Zooplankton composition in the southwestern Sea of Marmara during the summer season. COMU J. Mar. Sci. Fish, 8 (1): 97-102. doi:10.46384/jmsf.1719494

upper pelagic food web, beginning with primary producers (Cushing, 1990; Clark, 1992).

The Sea of Marmara (SoM) is a semi-enclosed marine system that serves as a transition zone between the Black Se and Mediterranean Sea via the narrow Istanbul and Çanakkale Straits. Topographically, the SoM features three deep basins exceeding 1000 m in depth and an extensive shallow shelf area less than 100 m deep in its southern half. The SoM is characterized by distinct stratification: less saline Black Sea waters flow in through the Istanbul Strait, while denser, more saline waters from the Aegean enter through the Çanakkale Strait (Beşiktepe *et al.*, 1994). The southwestern part of the SoM, encompassing Erdek Bay, the Southern Marmara Islands, and adjacent shelf areas, constitutes a distinctive ecological and oceanographic sub-region within the basin. This region is shaped by complex interactions among physical dynamics, biogeochemical gradients, and biological communities, and has long supported rich marine biodiversity (Altuğ *et al.*, 2011). It also serves as a key spawning and nursery ground for several fish species (Daban *et al.*, 2024) and supports regional small-scale fisheries.

Zooplankton studies conducted in the SoM remain limited and have generally focused on fisheries-related objectives (Yılmaz and İşinibilir, 2016). While several studies have evaluated zooplankton communities in the northeastern parts of the SoM (Yılmaz, 2002; Yılmaz, 2015; Bedikoğlu *et al.*, 2020), particularly in the eastern İzmit Bay (İşinibilir *et al.*, 2008; İşinibilir Okyar *et al.*, 2015), comparable data for the southwestern part, including Erdek Bay, are lacking (İşinibilir, 2010; Toklu-Alıçlı *et al.*, 2014). Despite its high biodiversity (Altuğ *et al.*, 2011) and relatively low anthropogenic pressure (Toklu-Alıçlı and Balkıs-Özdelice, 2014), zooplankton studies in Erdek Bay remain scarce, and no recent data are available.

This study aims to evaluate zooplankton composition, diversity, abundance, and associated environmental parameters in the inner and outer parts of Erdek Bay during two consecutive summer periods (2019 and 2020), to provide an updated dataset and baseline information before the mucilage crisis in 2021 for this ecologically valuable region.

Material and Methods

Zooplankton samples were collected during the summer periods of 2019 and 2020 from two stations located in the inner and outer parts of Erdek Bay (Figure 1). Sampling was conducted from the upper 20 meters of the water column using a WP2 - net (0.57 m mouth diameter, 200 µm mesh size). All samples were fixed in a borax-buffered formaldehyde solution at a final concentration of 4%. Mesozooplankton were identified to the lowest possible taxonomic level using Alden *et al.* (1982). Abundances were expressed as individuals per cubic meter (ind. m^{-3}). Replicate subsamples (1–10 mL) were taken using Stempel pipettes, with volumes ranging from 1/50 to 1/500 of the total sample, depending on organism density and composition. Taxonomic identifications were performed under a LEICA MZ125 stereo microscope. Temperature, salinity and,dissolved oxygen (DO) of the water column were measured at the surface and at depths of 5, 10, 15, 20, and 30 meters using a multi-parameter probe (YSI Professional Pro Plus). In addition, water samples were collected from these depths using 5 L Niskin bottles for the analysis of chlorophyll-a (Chl-a) and dissolved oxygen. Chlorophyll-a concentrations were determined using the acetone extraction method (Parsons *et al.*, 1984), and DO was measured according to the Winkler titration method, following the guidelines of APHA (2012). For the interpretation of environmental parameters, values were averaged across the zooplankton sampling depth (upper 20 meters) to ensure consistency with the biological data.

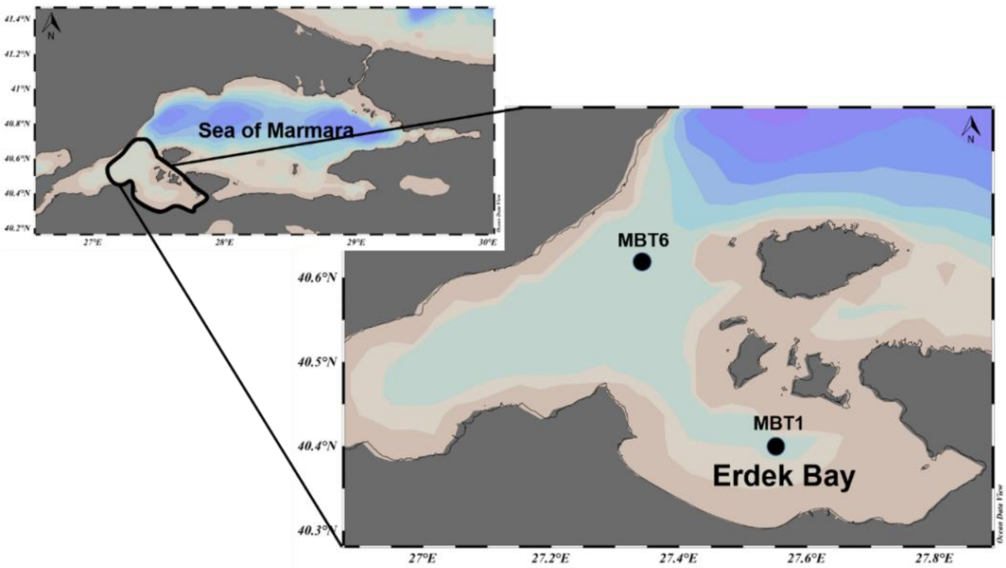

Figure 1. Sampling stations (indicated by black dots) and the location of the Sea of Marmara
Coordinates for MBT1 27.536E 40.422N, and MBT6 27.373E 40.623N)

Data were examined per sampling stations and years. Zooplankton abundance data were log(x+1) transformed to stabilize variance and reduce the influence of dominant taxa in multivariate analyses. The resulting resemblance matrix was used to conduct hierarchical cluster analysis using the group-average linkage method, producing a dendrogram to visualize patterns of community similarity among samples. To compare zooplankton community diversity and evenness between the two sampling periods (summers of 2019 and 2020), the Shannon-Wiener diversity index (H’) and Pielou’s evenness index (J’) were calculated based on abundance data. All statistical analyses were performed using PRIMER7 + PERMANOVA software (v.7.0; PRIMER-E).

Results and Discussion

Upper layer temperature in Erdek Bay ranged between 24.9 and 25.2 °C during the summers of 2019 and 2020, while salinity varied between 23.5 and 27.8 psu. Surface chlorophyll-a (Chl-a) concentrations were higher in 2019 compared to 2020. Although Chl-a values remained consistently below 1 µg L^{-1} in both years, concentrations at MBT1 (hereafter, inner bay) were lower than those recorded at MBT6 (hereafter, outer bay). In contrast, an opposite pattern was observed for dissolved oxygen (DO) concentrations, with surface DO levels lower in 2019 than in 2020. No consistent spatial pattern was observed between stations: DO levels were higher in the surface waters of the inner bay in 2019, whereas in 2020, higher values were recorded in the outer bay (Fig. 2).

In the zooplankton community, species number varied between 10 and 15. The lowest number of species (10) was recorded at the outer bay station in 2019, while the highest species richness was observed at the inner bay station in 2020. In both years, species number in the outer bay remained lower than in the inner bay. The Shannon-Wiener and Pielou evenness indices were higher in 2020 than in 2019. While diversity indices were higher in the outer bay in 2019, they were lower in 2020. The most diverse and compositionally even zooplankton community was recorded at the inner bay station in 2020 (Fig. 2).

Zooplankton abundance in both the inner and outer bays decreased by approximately three- and four-fold, respectively, in 2020 compared to 2019. In both years, zooplankton abundance at the outer bay station was higher than that at the inner bay. The highest abundance was recorded at the outer bay in 2019 (19,681 ind. m^{-3}), while the lowest value was observed at the inner bay in 2020 (4,869 ind. m^{-3}) (Fig. 2).

At the group level, Copepoda abundance remained lower than that of Cladocera throughout the study period. Previous studies also reported Cladocera dominance in the summer zooplankton community of the region in 2006, as well as in the eastern SoM between 2004 and 2008 (İşinibilir, 2010; Yılmaz, 2015; Bedikoğlu *et al.*, 2022). The high zooplankton abundance observed in 2019 coincided with elevated Chl-a concentrations, while salinity and dissolved oxygen levels were lower compared to 2020.

Throughout the study, a total of 20 distinct taxa/groups were identified. These included 4 Copepoda species, 5 Cladocera species, 4 holoplanktonic groups, 7 meroplanktonic groups, and 1 jellyfish group (Table 1). In a previous study conducted in 2006–2007, which used vertical hauls through the entire water column in the region, 27 copepod species were reported (Altuğ *et al.*, 2011). Another study carried out between 2006 and 2008, based on vertical hauls from 30 m to the surface, reported 12 copepod species in the zooplankton assemblage (Toklu-Alıçlı *et al.*, 2014). Differences in copepod species number observed among studies conducted during similar periods but using different sampling depths were attributed to the contribution of Mediterranean-origin species.

In 2019, findings from the present study indicated a decline in copepod species richness in the region, while the number of Cladocera species remained unchanged. The dominant copepod species was *Paracalanus parvus*, while *Penilia avirostris* was the most prominent among Cladocera (Table 1). In both years, the copepod species *P. parvus* and *Acartia clausi* were among the most abundant. Within Cladocera, *P. avirostris* and *Pseudevadne tergestina* stood out. Among holoplankton, *Oikopleura dioica* was prominent, while Gastropoda larvae were the leading group among meroplankton. In another study conducted at similar sampling depths (vertical hauls from 30 m) during 2006–2008, the dominant zooplankton species were again reported as *A. clausi* and *P. parvus* (Toklu-Alıçlı *et al.*, 2014).

The increase in zooplankton abundance observed in 2019 was primarily driven by the high dominance of *P. avirostris*, followed by *P. parvus* as the second most abundant species. As a result, a similarity rate exceeding 70% was determined between the study years and stations. In 2019, due to the increase in a single dominant species and lower diversity index values, inter-station similarity was approximately 75%. In contrast, in 2020, which was characterized by relatively lower abundance and higher diversity index values, inter-station similarity increased to approximately 83% (Fig. 3).

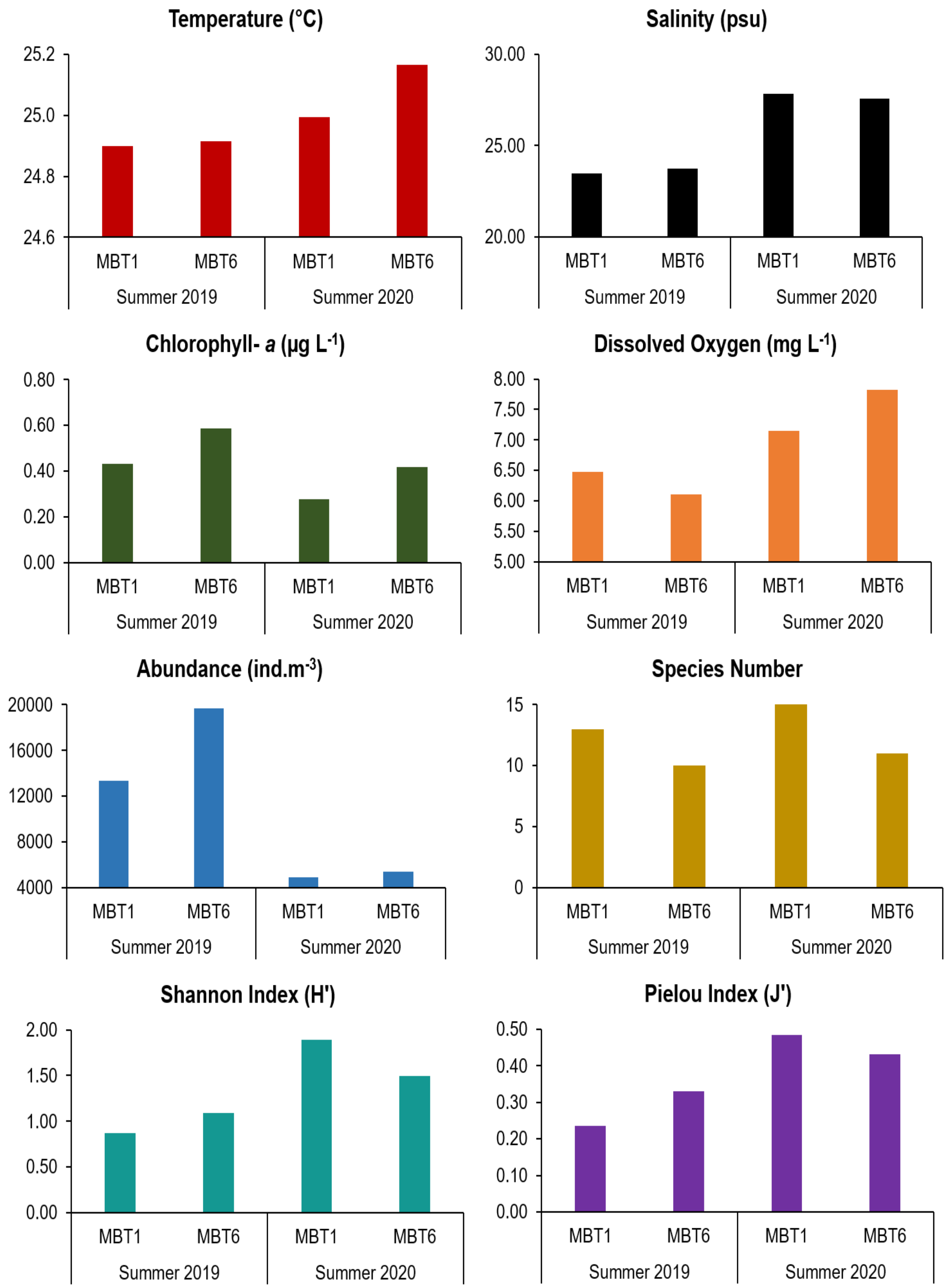

Figure 2. Changes in environmental parameters, abundance, species number and diversity index' at MBT1 and MBT2 stations in summer 2019 and 2020

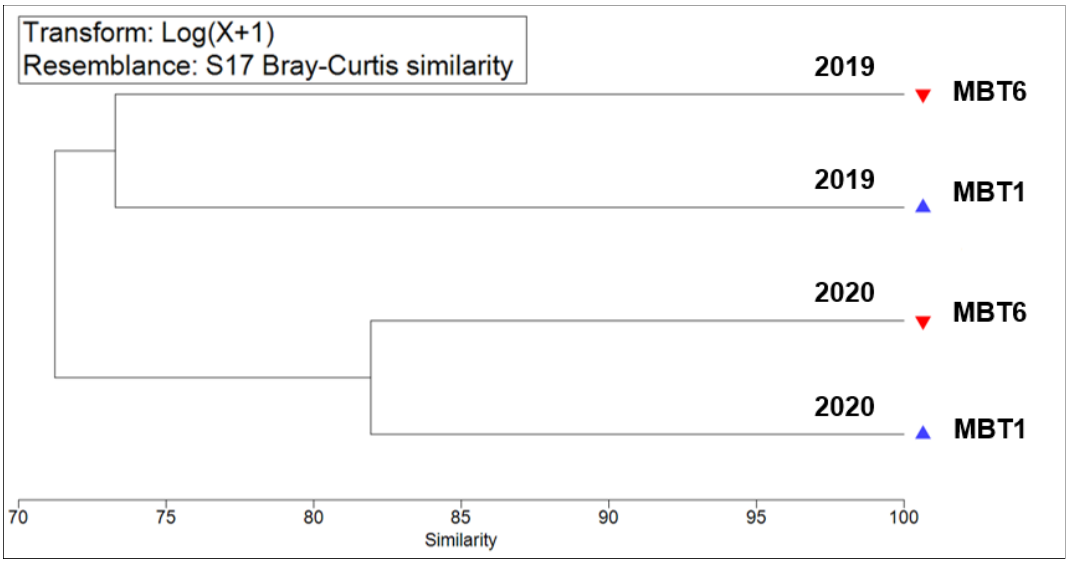

Figure 3. Hierarchical cluster dendrogram (Bray-Curtis similarity, log(x+1) transformed abundance data) of zooplankton communities at MBT1 and MBT2 stations in 2019 and 2020.

Conclusion

The Sea of Marmara (SoM) is a highly vulnerable semi-enclosed marine ecosystem that has undergone significant ecological changes over the past three decades (Demirel *et al.*, 2023). This study, conducted in the relatively understudied southwestern region of Erdek Bay, provides an updated assessment of the summer zooplankton community composition for the years 2019 and 2020. In 2020, zooplankton abundance sharply decreased compared to 2019, coinciding with a decline in chlorophyll-a concentrations. Despite this reduction in abundance, diversity indices were higher in 2020, indicating a shift in community composition. As the most recent previous study in this region dates back to the early 2010s, the present research helps fill a decade-long data gap. Although zooplankton communities are generally known to respond strongly to environmental variability, this study did not reveal consistent relationships with the measured environmental parameters. This is likely due to the limited temporal resolution of the dataset, which was restricted to two discrete summer periods. Therefore, long-term monitoring with higher temporal resolution is needed to more accurately assess temporal dynamics in zooplankton community structure.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

Dalida Bedikoğlu: Study design, sample, collection, species identification, data analysis, writing original draft preparation. Nazlı Demirel: Supervision, funding, study design, sample collection, writing reviewing, editing.

Ethics Approval

Ethics committee approval is not necessary for this study.

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