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# Assessment of the Spatial and Temporal Variation of Mesozooplankton in the Southern Black Sea, Türkiye

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**Research Article**

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**Abstract**
This study investigated the taxonomic composition, abundance, and biomass values of mesozooplankton in the marine area in front of two important rivers (Sakarya River and Yeşilırmak River) and the largest port located on the Black Sea coast in Türkiye (Samsun Port) in July 2019 and January 2020. The average mesozooplankton abundance and biomass were 4187.3 ind. m$^{-3}$ and 89.7 mg m$^{-3}$ in Sakarya River, 3638.5 ind. m$^{-3}$ and 78.2 mg m$^{-3}$ in Samsun Port, and 3327.6 ind.m$^{-3}$ and 77.6 mg m$^{-3}$ in Yeşilırmak River, respectively. In July 2019, the highest abundance value of mesozooplankton (8581 ind. m$^{-3}$) was recorded at SAK08 station off Sakarya River due to the copepod *Acartia clausi* (3279 ind. m$^{-3}$). In July 2019, the highest biomass value of mesozooplankton (209.34 mg m$^{-3}$) was found at YSL07 station off Yeşilırmak River with the contribution of the copepod *Centropages ponticus* (77.90 mg m$^{-3}$). In January 2020, the highest abundance and biomass values of mesozooplankton (4035 ind. m$^{-3}$ and 66.45 mg m$^{-3}$) were detected at SLI05 station off Samsun Port due to copepod *Acartia clausi*. A difference in mesozooplankton species composition between the two sampling periods was identified. While Cladocera species and copepod *Acartia tonsa* were exclusive at the sampling stations in July 2019, copepod *Calanus euxinus*, *Pseudocalanus elongatus* and *Oithona similis* were observed at the sampling stations in January 2020. Also, in January 2020, the presence of freshwater Cladocera species was detected off Sakarya River. The changes in biodiversity were determined to depend on temperature changes and riverine input.

**Keywords:** Species composition, abundance, biomass, Sakarya River, Samsun Port, Yeşilırmak River

## Güney Karadeniz'in Mesozooplanktonun Mekansal ve Zamansal Değişiminin Değerlendirilmesi

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**Öz**
Mevcut çalışmada, Temmuz 2019 ve Ocak 2020'de Türkiye'nin Karadeniz kıyılarında yer alan iki önemli nehir (Sakarya Nehri ve Yeşilırmak Nehri) ile Karadeniz'in en büyük limanı olan Samsun Limanı önündeki denizel alandaki mesozooplanktonun taksonomik kompozisyonu, bolluk ve biyokütle değerleri incelenmiştir. Ortalama mesozooplankton bolluğu ve biyokütlesi sırasıyla Sakarya Nehri'nde 4187.3 birey m$^{-3}$ ve 89.7 mg m$^{-3}$, Samsun Limanı'nda 3638.5 birey m$^{-3}$ ve

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78.2 mg m$^{-3}$ ve Yeşilırmak Nehri'nde 3327.6 birey m$^{-3}$ ve 77.6 mg m$^{-3}$ olarak hesaplanmıştır. Temmuz 2019'da mezozooplanktonun en yüksek bolluk değeri, Sakarya Nehri açıklarındaki SAK08 istasyonunda kopepod *Acartia clausi*'nin yüksek katkısı (3279 birey m$^{-3}$) nedeniyle kaydedilmiştir. Temmuz 2019'da mezozooplanktonun en yüksek biyokütle değeri ise Yeşilırmak Nehri açıklarındaki YSL07 istasyonunda, kopepod *Centropages ponticus*'un yüksek katkısıyla (77.90 mg m$^{-3}$) belirlenmiştir. Ocak 2020'de mesozooplanktonun en yüksek bolluk ve biyokütle değerleri (4035 birey m$^{-3}$ ve 66.45 mg m$^{-3}$) Samsun Limanı açıklarındaki SLI05 istasyonunda kopepod *Acartia clausi*'nin yüksek katkısı ile tespit edilmiştir. Mesozooplankton tür kompozisyonunda iki örnekleme dönemi arasında farklılık saptanmıştır. Cladocera türleri ve copepod *Acartia tonsa* Temmuz 2019'da örnekleme istasyonlarında tespit edilmişken, *Calanus euxinus*, *Pseudocalanus elongatus* ve *Oithona similis* Ocak 2020'de örnekleme istasyonlarında gözlemlenmiştir. Ayrıca Ocak 2020'de Sakarya Nehri açıklarında tatlısu Cladocera türlerinin varlığı saptanmıştır. Biyoçeşitlilikteki değişikliklerin sıcaklık değişimlerine ve nehir girdisine bağlı olduğu belirlenmiştir.

**Anahtar Kelimeler:** Tür kompozisyonu, bolluk, biyokütle, Sakarya Nehri, Samsun Limanı, Yeşilırmak Nehri

## Introduction

Carried by water currents or slowly floating vertically in the water column, zooplankton is a key group between primary producers and secondary consumers [1]. Zooplankton studies have focused on mesozooplankton (0.2–20 mm) due to its significant role in the marine ecosystem and its contribution to Carbon cycling. Being the main component as a primary consumer in the marine food pyramid, mesozooplankton is the main predator of microplankton and the prey of fish larvae and pelagic fish. Thus, it is an important element in the marine ecosystem playing a role in marine productivity and biogeochemical cycles [2]. Exposed to various environmental conditions, mesozooplankton demonstrates significant seasonal and spatial variations, both in terms of species composition and quantitative data of individual species and their distribution [3, 4]. Temperature [5, 6], anthropogenic impact [7, 8] and water current [9] are among the significant environmental factors that have an impact on the distribution, diversity and quantity of mesozooplanktonic organisms in the Black Sea coastal pelagic ecosystem. Coastal areas under the influence of natural and anthropogenic activities are highly susceptive to environment variability [10]. Responding rapidly to environmental changes due to their short life cycles [11], mesozooplankton is one of the major indicators of environmental changes and pressures in coastal waters [12, 13]. The main objective of the present study is to determine the structure of the coastal mesozooplankton community located off marine areas in front of Sakarya River, Samsun Port, and Yeşilırmak River. The data obtained can be used as background for quantitative assessments in the future.

## Materials and Methods

### Study Regions

Sakarya River is the third longest river in Türkiye (821 km) and the largest river in the Northwestern Anatolia. It originates from Afyonkarahisar province in the Central Western Anatolia and flows into the Black Sea in the Karasu district of Sakarya province (Figure 1). The average water quantity discharged into the Black Sea from the Sakarya River is 193 $m^3$ $s^{-1}$. Yeşilırmak River which is approximately 519 km long originates from Sivas province in Central Anatolia and flows into the Black Sea in Çarşamba district of Samsun province. It is the second-longest river in the Black Sea Region of Türkiye. It has an average annual flow rate of 151 $m^3$ $s^{-1}$. Both rivers are utilized for municipal water needs of settlements and industrial establishments for agricultural irrigation and wastewater discharge. They supply potable and irrigation water to the region via the dams built on them [14, 15]. Samsun Port is the largest port on the Black Sea coast of Türkiye which has a wide, international-level hinterland. The delta of Kızılırmak is located to the west and the delta of Yeşilırmak is located to the east of Samsun Port which is situated in a geographically and geomorphologically significant location [16].

### Sampling and Laboratory Studies

The study was performed on 6–13 July 2019 (summer season) and 10–18 January 2020 (winter season) at a total of 13 stations in marine areas in front of Sakarya River, Samsun Port, and Yeşilırmak River in Türkiye (southern Black Sea) (Figure 1). Salinity and temperature of the sea surface were measured using SeaBird SBE25Plus CTD+DO (SBE4 conductivity, SBE3 temperature, and depth; plus, SBE43 dissolved Oxygen) and SBE 32 Carousel Water Sampler (8-liter bottles), which was installed on the R/V TUBITAK MARMARA research vessel. Dissolved Oxygen concentration (mg $L^{-1}$) was measured using the Iodometric Winkler test method [17]. The Chlorophyll-*a* concentrations (µg $L^{-1}$) were measured by the acetone extraction method in the Spectrophotometer [18]. The mesozooplankton samples were collected using a UNESCO WP2 net (200 µm mesh size, 57 cm mouth diameter) cast from R/V TÜBİTAK Marmara during daytime with a single vertical haul. Following the vertical haul, the net was rinsed gently and the contents of the cod ends of the plankton net were transferred into a plastic bottle and fixed in borax-buffered formaldehyde (seawater solution to a final concentration of 4%) for identification and enumeration of mesozooplankton individuals. In the laboratory, the samples were concentrated to 50 ml or 75 ml, depending on the sample density. Two sub-samples were taken from a Stempel pipette (1 ml) in a homogenized sample. The identification and counting of the mesozooplankton individuals were conducted using a zooplankton counting apparatus (Bogorov Rass Chamber) under a stereomicroscope (Novex RZ 65500). For species that did not appear during subsampling and for rare and large organisms (such as Chaetognatha and Decapoda larvae), the whole sample was investigated [19]. The results were averaged and extrapolated to the whole sample.

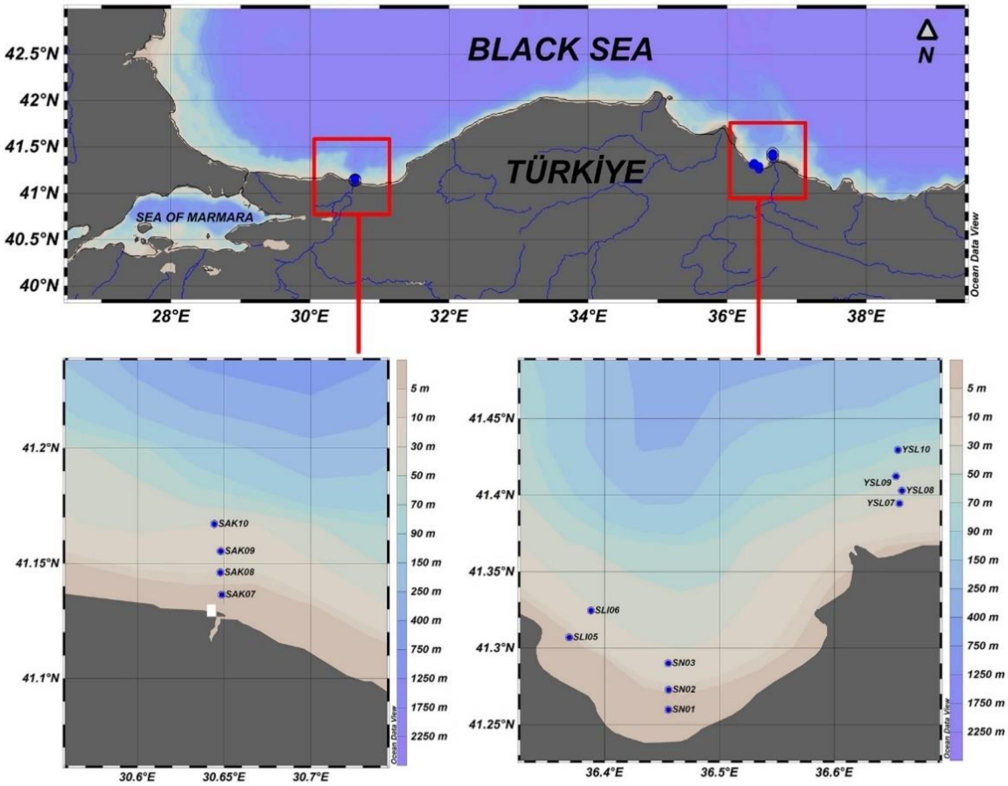


***Figure 1.*** *Location of sampling stations*

According to Petipa [20] and Niermann et al. [21], the biomass transformations were based on the wet individual weights. The mesozooplankton abundance and biomass results were given as individuals per cubic meter (ind.) $m^{-3}$ and mg per cubic meter (mg $m^{-3}$). All taxa were identified taxonomically to the species level except for the Meroplankton larvae. Mesozooplankton species identification was made mainly after Bradford-Grieve et al. [22] and Conway et al. [23] and the taxonomic nomenclature according to the World Register of Marine Species (WoRMS).

## Statistical Analysis

The Spearman rank correlation was applied to assess correlations of the abundance of mesozooplankton species/taxa with environmental parameters, and the abundance of *Noctiluca scintillans* (SPSS 21 IBMCrop., Armonk, NY, USA). Shannon–Weaver diversity index (H′) was applied to the species abundance data to explain the mesozooplankton quantitative data regarding the community assemblage. Abundance data were square root transformed to reduce the dominance of heavily abundant species/groups based on the Bray–Curtis rank similarity matrix. Group average hierarchical cluster analysis (CLUSTER) was applied to test similarities in mesozooplankton assemblage among stations

(SAK07, SAK08, YSL07, SN01 etc.). One-way analysis of similarity (ANOSIM) was applied on mesozooplankton species/taxa abundance to test whether there was a significant difference between the regions (Sakarya River, Samsun Port, Yeşilırmak River). The similarity percentage (SIMPER) procedure was used to reveal mesozooplankton species/taxa responsible for average similarities within regions (Sakarya River, Samsun Port, Yeşilırmak River) and average dissimilarity between the pair combination of regions, and to determine the contribution rates. CLUSTER, ANOSIM, SIMPER and Shannon-Weaver diversity index were conducted using PRIMER 5.0 software.

## Results

### Environmental Parameters

The surface seawater temperature values of the sampling stations ranged from 25.35 °C to 26.52 °C in July 2019 (average: 25.95 °C) and from 10.81 °C to 11.78 °C in January 2020 (average: 11.17 °C). The surface seawater salinity values fluctuated from 15.84 to 18.11 psu in July 2019 (average: 17.56 psu), and 15.73 to 18.34 psu in January 2020 (average: 17.52 psu). The surface seawater concentrations of dissolved Oxygen (DO) values were between 7.08 and 11.65 mg L$^{-1}$ in July 2019 (average: 7.99 mg L$^{-1}$) and between 8.69 and 9.83 mg L$^{-1}$ in January 2020 (average: 9.32 mg L$^{-1}$). The minimum and maximum concentrations of surface seawater Chlorophyll-*a* varied between 0.08 µg L$^{-1}$ and 18.31 µg L$^{-1}$ in July 2019 (average: 2.14 µg L$^{-1}$) and between 0.68 µg L$^{-1}$ and 2.34 µg L$^{-1}$ in January 2020 (average: 1.24 µg L$^{-1}$) (Figure 2).

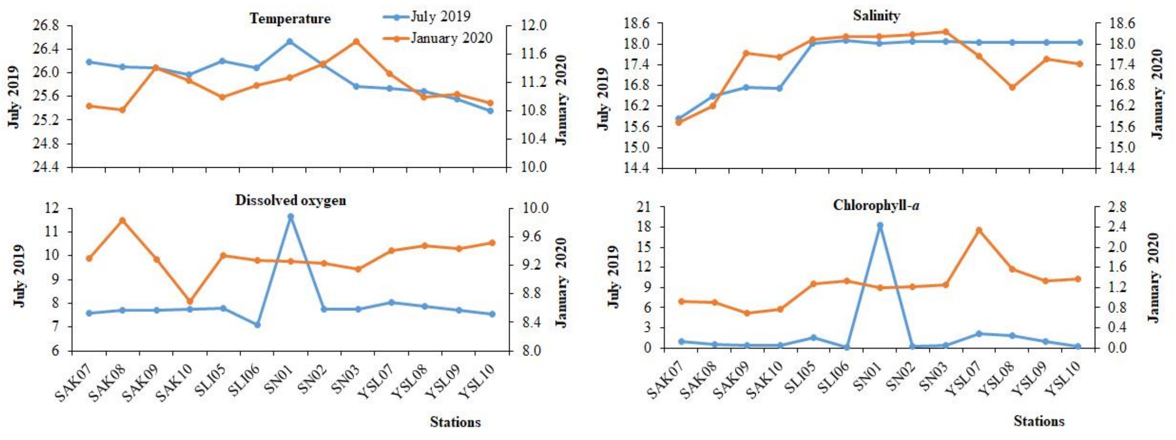


***Figure 2.*** *The seawater temperature (°C), salinity (psu), dissolved Oxygen (mg L$^{-1}$) and Chlorophyll-a (µg L$^{-1}$) concentration at a depth of 1 m at sampling stations*

### Taxonomic Composition, Abundance and Biomass of Mesozooplankton Species/taxa

The average mesozooplankton abundance and biomass values were higher in July 2019 than in January 2020 in three regions (Table 1). The mesozooplankton abundance and biomass values varied between 4838–8581 ind. m$^{-3}$ and 102–179 mg m$^{-3}$ in Sakarya River, 3652–7020 ind. m$^{-3}$, and 72–198 mg m$^{-3}$ in Samsun Port and 3363–8001 ind. m$^{-3}$ and 78–209 mg m$^{-3}$ in Yeşilırmak River in July 2019. In January

2020, these values varied between 1875–2642 ind. m$^{-3}$ and 32–59 mg m$^{-3}$ in Sakarya River, 1156–4036 ind. m$^{-3}$, and 15–66 mg m$^{-3}$ in Samsun Port and 729–2016 ind. m$^{-3}$ and 8–28 mg m$^{-3}$ in Yeşilırmak River (Figure 3).

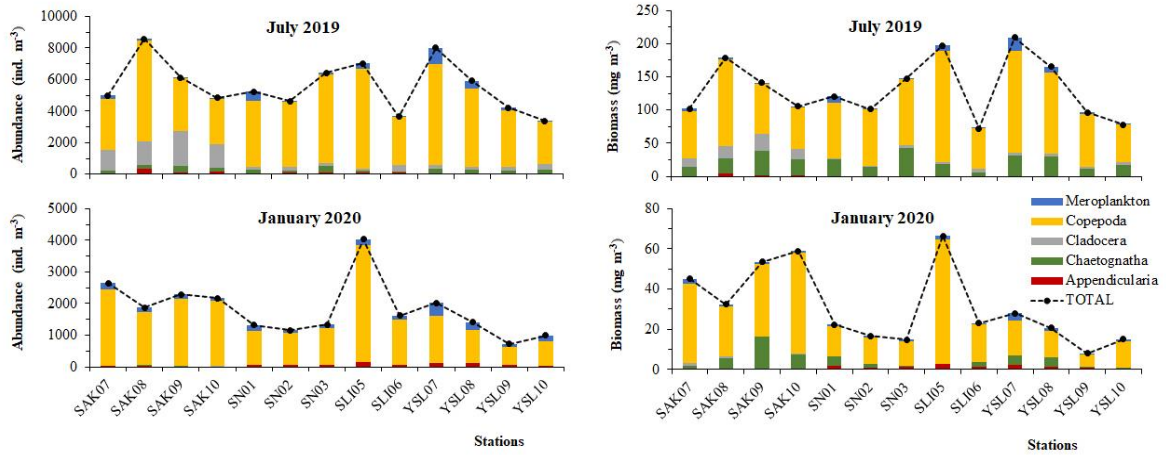


***Figure 3.*** *Abundance (ind. m$^{-3}$) and biomass (mg m$^{-3}$) values of mesozooplankton groups at sampling stations*

*Oikopleura dioica* (Appendicularia) and *Parasagitta setosa* (Chaetognatha) were detected at all stations during the study period. The abundance and biomass of *O. dioica* in July 2019 were 3.3–349 ind. m$^{-3}$ and 0.05–4.3 mg m$^{-3}$ in Sakarya River, 16.3–122 ind. m$^{-3}$ and 0.05–0.71 mg m$^{-3}$ in Samsun Port, 3–47 ind. m$^{-3}$ and 0.01–0.52 mg m$^{-3}$ in Yeşilırmak River (Figure 3). The abundance and biomass of the same species in January 2020 were 6.5–37 ind. m$^{-3}$ and 0.09–0.3 mg m$^{-3}$ in Sakarya River, 49–138 ind. m$^{-3}$ and 0.7–2.7 mg m$^{-3}$ in Samsun Port, 23–105 ind. m$^{-3}$ and 0.3–2.5 mg m$^{-3}$ in Yeşilırmak River (Figure 3). In July 2019, the minimum and maximum abundance of *Parasagitta setosa* were in the range of 217–419 ind. m$^{-3}$ in Sakarya River, 91–372 ind. m$^{-3}$ in Samsun Port and 165–325 ind. m$^{-3}$ in Yeşilırmak River. The minimum and maximum biomass of the species in summer were in the range of 14.4–37 mg m$^{-3}$ in Sakarya River, 5.8–43 mg m$^{-3}$ in Samsun Port and 11–32 mg m$^{-3}$ in Yeşilırmak River (Figure 3). In January 2020, the minimum and maximum abundance of *P. setosa* ranged between 5 and 9.5 ind. m$^{-3}$ in Sakarya River, 0.8 and 4.3 ind. m$^{-3}$ in Samsun Port, and 1.6 and 5.2 ind. m$^{-3}$ in Yeşilırmak River. The minimum and maximum biomass of the species in winter ranged between 1.5 and 16.4 mg m$^{-3}$ in Sakarya River, 0.2 and 4.7 mg m$^{-3}$ in Samsun Port and 0.4 and 4.7 mg m$^{-3}$ in Yeşilırmak River (Figure 3).

Copepoda was the predominant group, with the highest abundance and biomass values among the mesozooplankton in the sampling period. The abundance and biomass of Copepoda (adult+copepodit+nauplii) were 2882–6394 ind. m$^{-3}$ and 64–130 mg m$^{-3}$ in Sakarya River, 3055–6312 ind. m$^{-3}$ and 61–168 mg m$^{-3}$ in Samsun Port, 2680–6399 ind. m$^{-3}$ and 56–153 mg m$^{-3}$ in Yeşilırmak River in July 2019 (Figure 3).

***Table 1.*** *The average abundance (ind. $m^{-3}$) and biomass (mg $m^{-3}$) of mesozooplankton species/taxa in front of Sakarya River, Samsun Port and Yeşilırmak River*

| | **Average Abundance (ind.$m^{-3}$)** | | | | | | **Average Biomass (mg $m^{-3}$)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Sakarya River** | | **Samsun Port** | | **Yeşilırmak River** | | **Sakarya River** | | **Samsun Port** | | **Yeşilırmak River** | |
| **Species** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** |
| *Oikopleura dioica* | 158.5 | 17.2 | 82.2 | 71.75 | 26.3 | 71.85 | 1.8 | 0.18 | 0.5 | 1.56 | 0.23 | 1.26 |
| *Evadne spinifera* | 10.5 | | | | 1.7 | | 0.04 | | 0 | | 0.007 | |
| *Penilia avirostris* | 451.8 | | 83.1 | | 118.1 | | 12.7 | | 2.33 | | 3.31 | |
| *Pleopis polyphemoides* | 126.9 | 8.1 | 9.7 | | 13.1 | | 1.14 | 0.07 | 0.09 | | 0.12 | |
| *Pseudevadne tergestina* | 1010 | | 126.4 | | 133.5 | | 4.04 | | 0.51 | | 0.53 | |
| *Bosmina longirostris* | | 2.9 | | | | | | 0.40 | | | | |
| *Ceriodaphnia reticulata* | | 0.3 | | | | | | 0.05 | | | | |
| *Chydorus sphaericus* | | 0.2 | | | | | | 0.02 | | | | |
| *Daphnia cucullata* | | 0.2 | | | | | | 0.02 | | | | |
| *Daphnia magna* | | 0.8 | | | | | | 0.11 | | | | |
| *Pleuroxus aduncus* | | 0.2 | | | | | | 0.02 | | | | |
| *Parasagitta setosa* | 283.4 | 7.3 | 202.6 | 2.04 | 242.4 | 2.63 | 24.8 | 7.6 | 21.2 | 1.97 | 22.3 | 2.55 |
| *Acartia clausi* | 1760.7 | 682.7 | 1787.3 | 630.03 | 1456 | 308.47 | 44.3 | 15.1 | 43.8 | 12.7 | 36.04 | 5.46 |
| *Acartia tonsa* | 797.9 | | 279.2 | | 241.2 | | 16.4 | | 6.5 | | 5.01 | |
| *Acartia* sp. | 953.2 | | 1512.5 | | 1069.2 | | 10.7 | | 18.2 | | 12.5 | |
| *Calanus euxinus* | | 42.2 | 0.2 | 12.88 | | 4.65 | | 11.2 | 0.01 | 1.19 | | 1.57 |
| *Centropages ponticus* | 342.4 | 0.9 | 1041.9 | | 1638.7 | | 13 | 0.04 | 30.7 | 0.006 | 49.02 | |
| *Oithona davisae* | 3.9 | 3.9 | 2.1 | 2.94 | 0.4 | 7.8 | 0.01 | 0.01 | 0.005 | 0.2 | 0.001 | 0.02 |
| *Oithona similis* | | 80.9 | | 44.81 | | 82.66 | | 0.4 | | 8.38 | | 0.36 |

*Table 1 continued…*

| | **Average Abundance (ind.m$^{-3}$)** | | | | | | **Average Biomass (mg m$^{-3}$)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Sakarya River** | | **Samsun Port** | | **Yeşilırmak River** | | **Sakarya River** | | **Samsun Port** | | **Yeşilırmak River** | |
| **Species** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** | **July 19** | **Jan. 20** |
| *Paracalanus parvus* | 94.2 | 1075.7 | 18.8 | 885.01 | 2.1 | 458.07 | 1 | 9.24 | 0.2 | 1.59 | 0.02 | 4.16 |
| *Pseudocalanus elongatus* | | 57.6 | | 40.36 | | 32.87 | | 1.64 | | 0.07 | | 0.7 |
| *Pontella mediterranea* | | | | | 0.8 | | | | | | 0.16 | 0.09 |
| Copepod nauplii | 2.8 | 123.5 | 12.8 | 65.79 | 2.1 | 87.87 | 0.003 | 0.12 | 0.013 | 12.7 | 0.002 | 0.02 |
| Actinotroch larvae | | 0.03 | | | | | | | | | | |
| Ascidian larvae | | 0.3 | | | | | | | | | | |
| Bivalve larvae | 14.5 | 113.8 | 17.7 | 116.18 | 37.4 | 187.19 | 0.07 | 0.57 | 0.09 | 0.6 | 0.19 | 0.94 |
| *Branchiostoma* | 0.1 | | | | | | | | | | | |
| Cirriped larvae | 72 | 10.1 | 151.3 | 18.10 | 252.5 | 40.84 | 1.61 | 0.19 | 2.43 | 0.32 | 4.01 | 0.67 |
| Cyphanout larvae | 2.3 | | | | 1.4 | | 0.003 | | | | 0.002 | |
| Decapod larvae | 5.9 | 0.1 | 15.2 | 0.21 | 41.9 | | | 0.004 | | 0.01 | | |
| Gastropod larvae | 6.7 | 0.4 | 10.5 | | 31.3 | 0.98 | 0.36 | 0.005 | 0.94 | | 2.6 | 0.01 |
| Polychaete larvae | 3.7 | 15.4 | 7.7 | 1.24 | 25.1 | 1.27 | 0.07 | 0.58 | 0.11 | 0.05 | 0.34 | 0.05 |
| Fish egg | 22 | 0.3 | 14.6 | | 18.5 | | 0.14 | | 0.29 | | 0.95 | |
| Fish larvae | 6.2 | 0.1 | 9.9 | | 14.4 | | | | | | | |
| *Noctiluca scintillans* | 111.6 | 321.9 | 2.5 | 267.05 | 2.8 | 209.76 | 9.67 | 28.3 | 0.22 | 23.5 | 0.24 | 18.5 |

Copepoda was represented by seven species, from which Acartiidae (*Acartia clausi* and *Acartia tonsa*) and *Centropages ponticus* revealed the highest abundances in the sampling sites in July 2019. The maximum abundance and biomass values of *A. clausi* were 3279 ind. $m^{-3}$ and 81 mg $m^{-3}$ at station SAK08; and the corresponding values were 1396 ind. $m^{-3}$ and 32.5 mg $m^{-3}$ for *A. tonsa* at station SLI05, 2772 ind. $m^{-3}$ and 34 mg $m^{-3}$ for *Acartia* sp. at station SN03 and 2750 ind. $m^{-3}$ and 78 mg $m^{-3}$ for *C. ponticus* at station YSL07 in July 2019. *Calanus euxinus* was only observed in the Samsun Port (1.1 ind. $m^{-3}$ and 0.05 mg $m^{-3}$ in SN03). *Pontella mediterranea* was only recorded in the Yeşilırmak River (3.3 ind. $m^{-3}$ and 0.65 mg $m^{-3}$ in YSL07) in summer. *Oithona similis* and *Pseudocalanus elongatus* were absent at all the sampling stations in summer (Figure 4A). In January 2020, the minimum and maximum abundances of Copepoda were in the range of 1676–2419 ind. $m^{-3}$ in Sakarya River, 1011–3703 ind. $m^{-3}$ in Samsun Port and 573–1500 ind. $m^{-3}$ in Yeşilırmak River. The minimum and maximum biomass values of Copepoda were in the range of 25–50 mg $m^{-3}$ in Sakarya River, 12–62 mg $m^{-3}$ in Samsun Port and 6–17 mg $m^{-3}$ in Yeşilırmak River in winter (Figure 3). Among the seven copepod species identified in the sampling regions in winter, *A. clausi* and *Paracalanus parvus* were dominant in terms of abundance, and *C. euxinus* was dominant in terms of biomass. The highest abundance and biomass values of *A. clausi* (2224 ind. $m^{-3}$ and 44.3 mg $m^{-3}$) and *P. parvus* (1283 ind. $m^{-3}$ and 13 mg $m^{-3}$) were recorded at station SLI05. The peak values of *C. euxinus* (58 ind. $m^{-3}$ and 26 mg $m^{-3}$) were found at station SAK10. *C. ponticus* was exclusively observed in Sakarya River (3.7 ind.$m^{-3}$ and 0.2 mg $m^{-3}$ in SAK08) in winter, and *A. tonsa*, *Acartia* sp. and *P. mediterranea* were absent in all the sampling stations in January 2020 (Figure 4A). Abundance and biomass values of Cladocera varied between 1267–2198 ind. $m^{-3}$ and 12.3–26 mg $m^{-3}$ in Sakarya River, 115–384 ind. $m^{-3}$ and 1.6–4.6 mg $m^{-3}$ in Samsun Port and 173–375 ind. $m^{-3}$ and 3.4–4.2 mg $m^{-3}$ in Yeşilırmak River in July 2019 (Figure 3). *Penilia avirostris* and *Pseudoevadne tergestina* were dominant among the identified four cladocerans in July 2019. Maximum abundance and biomass values of *P. avirostris* were 688 ind. $m^{-3}$ and 19.3 mg $m^{-3}$ at station SAK09. The highest abundance and biomass values of *P. tergestina* were 1406 ind. $m^{-3}$ and 6 mg $m^{-3}$ at station SAK09 (Figure 4B). The marine cladocerans were only represented by *Pleopis polyphemoides* in January 2020. This species was exclusively found at stations of the Sakarya River. Freshwater cladocerans were also identified in the Sakarya River (SAK07 and SAK08) in both seasons (Table 1).

The abundance and biomass values of meroplankton varied between 80–236 ind. $m^{-3}$ and 1–4 mg $m^{-3}$ in Sakarya River, 20.5–605 ind. $m^{-3}$ and 0.07–9.5 mg $m^{-3}$ in Samsun Port, 51–1045 ind. $m^{-3}$ and 0.6–20 mg $m^{-3}$ in Yeşilırmak River in July 2019, respectively (Figure 3). In January 2020, the abundance and biomass values of meroplankton varied between 83–187 ind. $m^{-3}$ and 0.8–2.3 mg $m^{-3}$ in Sakarya River, 93–193 ind. $m^{-3}$ and 0.6–1.9 mg $m^{-3}$ in Samsun Port, 101–409 ind. $m^{-3}$ and 0.5–3.5 mg $m^{-3}$ in Yeşilırmak River, respectively (Figure 3).

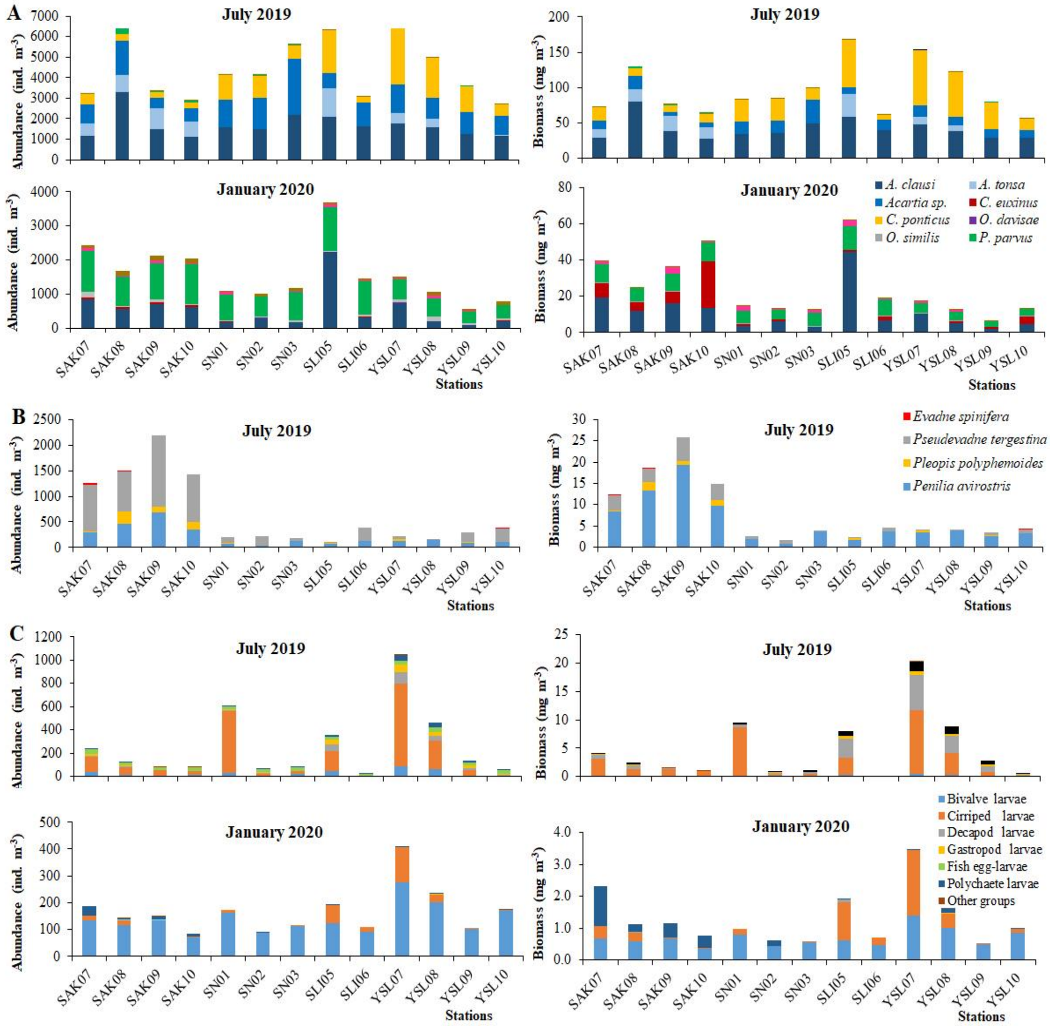


***Figure 4.*** *Abundance (ind. m$^{-3}$) and biomass (mg m$^{-3}$) values of (**A**) Copepoda species, (**B**) Cladoceran species and (**C**) Meroplanktonic groups (Other groups: Actinotroch larvae, Ascidian larvae, Branchiostoma, Cyphonaut larvae) at sampling stations*

Among the 11 meroplanktonic groups recorded in the study, cirriped larvae were dominant in July 2019 and bivalve veligers were dominant in January 2020. Maximum abundance and biomass values of cirriped larvae were 714 ind. m$^{-3}$ and 11.3 mg m$^{-3}$ in July 2019 at station YSL07. The highest abundance and biomass values of bivalve veligers were 276 ind. m$^{-3}$ and 1.4 mg m$^{-3}$ in January 2020 at station YSL07 (Figure 4C). The abundance and biomass values of *Noctiluca scintillans* were lower in July 2019. It was absent in the Samsun Port samples from stations SN01, SN03 and SLI06 and Yeşilırmak River region samples (except station YSL07). *N. scintillans* showed maximum abundance and biomass values of 401 ind. m$^{-3}$ and 35 mg m$^{-3}$ at station SAK08 in July 2019. The abundance and biomass of *N. scintillans* were 91–583 ind. m$^{-3}$ and 8–51 mg m$^{-3}$ in Sakarya River, 46–784 ind. m$^{-3}$ and 4–69 mg m$^{-3}$ in Samsun Port, 91–395 ind. m$^{-3}$ and 8–35 mg m$^{-3}$ in Yeşilırmak River in January 2020 (Figure 5A).

**Mesozooplankton Community Structure and Relationships with Environmental Parameters**

Shannon diversity index values were between 2.8–3.09 in Sakarya River, 2.10–2.51 in Samsun Port and 2.36–2.69 in Yeşilırmak River in July 2019. Shannon diversity index varied from 1.89 to 2.25 in Sakarya River, 1.73 to 2.13 in Samsun Port and 2.33 to 2.74 in Yeşilırmak River in January 2020. Shannon diversity index values determined in July 2019 are higher than those in January 2020 (except for station YSL08 in Yeşilırmak River). Lower Shannon diversity index values (ranging from 1.73 to 1.93) were detected in January 2020 (stations SLI05, SAK10, SN03 and SLI06) due to the numerical dominance of copepods *Paracalanus parvus* and *Acartia clausi* (Figure 5B).

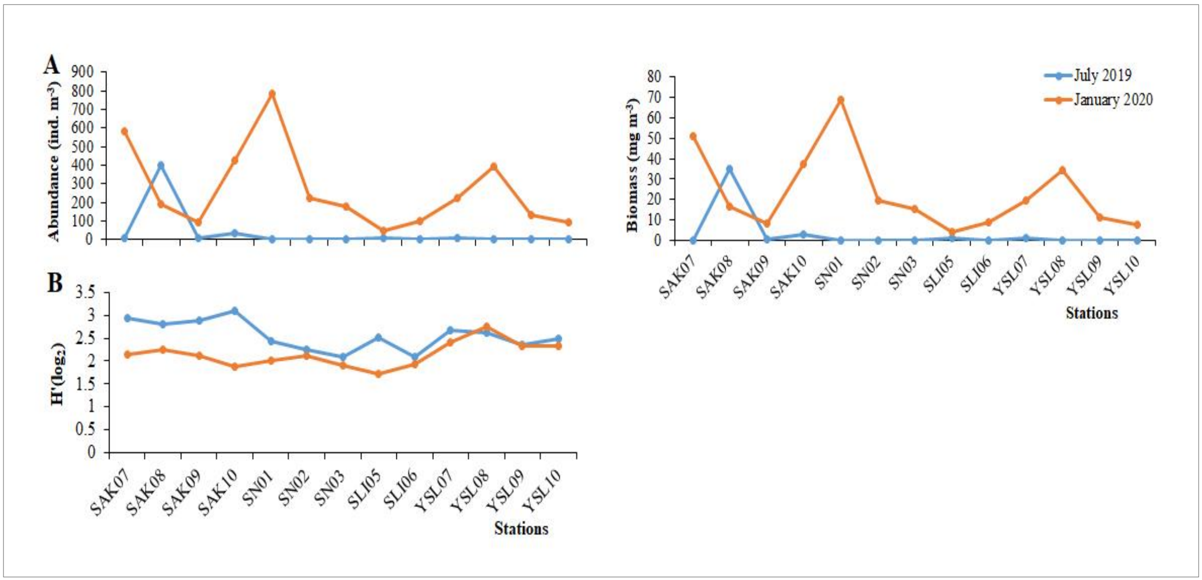


***Figure 5***. *(**A**) Abundance (ind. $m^{-3}$) and biomass (mg $m^{-3}$) values of Noctiluca scintillans at sampling stations. (**B**) The Shannon diversity index (H'($log_2$)) for mesozooplankton abundance for each month and sampling stations (absent N. scintillans)*

The cluster analysis classified stations into two groups at the 69% similarity level. The first cluster is composed of Sakarya River stations and the second one covered Samsun Port and Yeşilırmak River stations in July 2019 (Figure 6). The ANOSIM test revealed statistically significant differences in the abundances of mesozooplankton assemblages, and between different sampling regions (global R = 0.495, p = 0.003). While there was a statistically significant difference between Sakarya River and Samsun Port (global R = 0.788, p = 0.016) and Sakarya River and Yeşilırmak River group (global R = 0.771, p = 0.029), no difference was determined between Samsun Port and Yeşilırmak River group (global R = –0.056, p = 0.532) in July 2019. The SIMPER analysis showed that the intra-group average similarity value was at 82.61% in Sakarya River, 75.69% in Samsun Port and 78.36% in Yeşilırmak River in July 2019. The community of Sakarya River was characterized by a high abundance of the copepod *A. clausi*, and the cladoceran *P. tergestina*. Samsun Port and Yeşilırmak River were dominated by *A. clausi*, *Acartia* sp., and *C. ponticus*. The average dissimilarity percentages between the sampling regions were low in July 2019 according to the results of SIMPER analysis (Sakarya River and Samsun Port = 31.62%; Sakarya River and Yeşilırmak River = 29.94%; Samsun Port and Yeşilırmak River = 23.03%). The differences in mesozooplankton assemblages among regions were due largely to *A. tonsa*, *P. polyphemoides*, *P. tergestina* and *C. ponticus* based on the SIMPER analysis (Table 2).

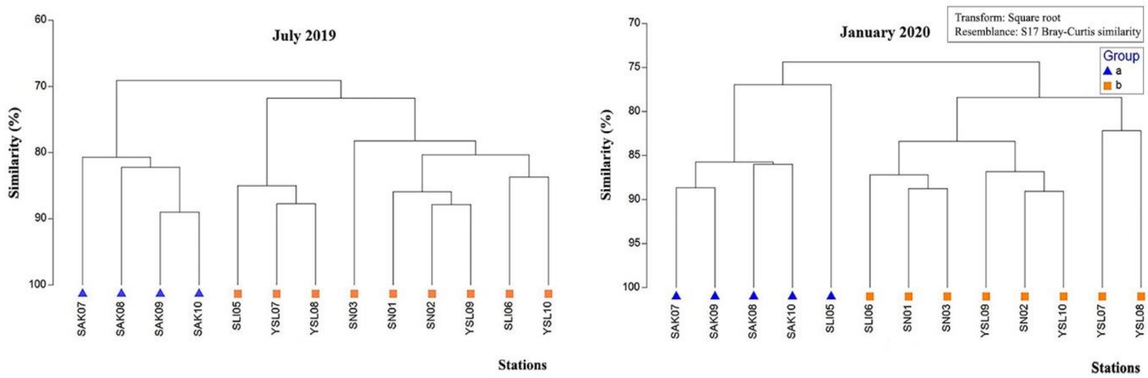


***Figure 6.*** *The cluster dendrogram showing relationships between stations, based on mesozooplankton abundance in July 2019 and January 2020*

According to the results of ANOSIM, the groups were selected at the 74% similarity level in the CLUSTER analysis (Figure 6), and the global R value was 0.466 ($p = 0.002$) in January 2020. While a statistically significant difference was evident between Sakarya River and Samsun Port (global R = 0.538, $p = 0.024$) and Sakarya River and Yeşilırmak River group (global R = 0.792, $p = 0.029$), no significant difference was found between Samsun Port and Yeşilırmak River group (global R = 0.125, $p = 0.19$) in January 2020. The SIMPER analysis showed that the intra-group average similarity value was at 86.27% in Sakarya River, 81.20% in Samsun Port and 79.35% in Yeşilırmak River in January 2020. The taxa with the highest contributions to the similarity at the Sakarya River, Samsun Port and Yeşilırmak River were *P. parvus*, *A. clausi* and bivalve veligers (Table 2). Similarity percentages showed an average dissimilarity of 22.38% between Sakarya River and Samsun Port, 27.34% between Sakarya and Yeşilırmak Rivers and 21.03% between Samsun Port and Yeşilırmak River. The SIMPER analysis showed that the taxa responsible for the dissimilarity between the sampling regions were *A. clausi* and *P. parvus* (Table 2). Total mesozooplankton abundance and biomass were positively correlated with temperature however negatively correlated with dissolved oxygen and the abundance of *N. scintillans* ($p < 0.01$). No correlations were found between the abundance and biomass of total mesozooplankton and salinity and Chlorophyll-*a*. The dominant species of summer samples—*A. clausi*, *A. tonsa*, *C. ponticus*, *P. avirostris*, *P. tergestina* and Cirripedia larvae—were positively correlated with temperature ($p < 0.01$), but negatively correlated with dissolved oxygen (except cirriped larva) ($p < 0.01$). The dominant taxa of winter—*P. parvus*, *C. euxinus* and bivalve veligers—were negatively correlated with temperature ($p <0.01$), but positively correlated with dissolved Oxygen ($p<0.01$; Table 3).

***Table 2***. *The percent contribution (%) of the mesozooplankton species to in–region similarity (red) or between–region dissimilarity (blue) from SIMPER analysis in July 2019 and January 2020*

| **July 2019** | | | | | | |
|---|---|---|---|---|---|---|
| | **Sakarya River** | | **Samsun Port** | | **Yeşilırmak River** | |
| | **Species** | **Contribution %** | **Species** | **Contribution %** | **Species** | **Contribution %** |
| **Sakarya River** | *A. clausi* | 16.94 | | | | |
| | *P. tergestina* | 14.35 | | | | |
| **Samsun Port** | *A. tonsa* | 17.70 | *A. clausi* | 26.96 | | |
| | *P. polyphemoides* | 15.03 | *Acartia* sp. | 22.01 | | |
| | | | *C. ponticus* | 15.82 | | |
| **Yeşilırmak River** | *P. tergestina* | 15.13 | *A. tonsa* | 15.16 | *A. clausi* | 21.71 |
| | *C. ponticus* | 14.53 | *C. ponticus* | 14.57 | *Acartia* sp. | 18.77 |
| | | | | | *C. ponticus* | 18.59 |
| **January 2020** | | | | | | |
| | **Sakarya River** | | **Samsun Port** | | **Yeşilırmak River** | |
| | **Species** | **Contribution %** | **Species** | **Contribution %** | **Species** | **Contribution %** |
| **Sakarya River** | *P. parvus* | 29.33 | | | | |
| | *A. clausi* | 23.15 | | | | |
| **Samsun Port** | *A. clausi* | 25.55 | *P. parvus* | 33.25 | | |
| | | | *A. clausi* | 17.50 | | |
| | | | Bivalvia | 12.32 | | |
| **Yeşilırmak River** | *P. parvus* | 19.73 | *A. clausi* | 23.67 | *P. parvus* | 26.40 |
| | *A. clausi* | 18.51 | *P.parvus* | 20.18 | *A. clausi* | 15.76 |
| | | | | | Bivalvia | 15.64 |

***Table 3.*** *The relationship between the abundance of mesozooplankton species/taxa, and the environmental parameters*

| | **Temperature** | **Salinity** | **Dissolved Oxygen** | **Chlorophyll-*a*** | ***N. scintillans*** |
|---|---|---|---|---|---|
| Mesozooplankton abundance | .842** | ns | -.587** | ns | -.544** |
| Mesozooplankton biomass | .822** | ns | -.601** | ns | -.570** |
| Total abundance of Copepoda | .802** | ns | -.566** | ns | -.570** |
| *A. clausi* | .768** | ns | -.508** | ns | -.569** |
| *A.tonsa* | .550** | ns | -.589** | ns | ns |
| *Acartia* sp. | .849** | ns | -.591** | ns | -.697** |
| *C. euxinus* | -.725** | ns | .654** | ns | .647** |
| *C. ponticus* | .752** | ns | -.609** | ns | -.735** |
| *O. davisae* | ns | ns | ns | ns | ns |
| *O. similis* | -.796** | ns | .705** | ns | .719** |
| *P. parvus* | -.682** | ns | .588** | ns | .758** |
| *P. elongatus* | -.798** | ns | .662** | ns | .751** |
| Copepod nauplii | -.719** | ns | .734** | ns | .581** |
| *O. dioica* | ns | ns | ns | ns | ns |
| *P. setosa* | .712** | ns | -.477* | ns | -.601** |
| Total abundance of Cladocera | .717** | ns | -.747** | -.511** | -.556** |
| *P. avirostris* | .806** | ns | -.649** | ns | -.628** |
| *P. polyphemoides* | .475* | -.443* | -.552** | ns | ns |
| *P. tergestina* | .790** | ns | -.778** | -.439* | -.650** |
| Meroplankton | ns | ns | ns | .557** | ns |
| Bivalve veligers | -.738** | ns | .783** | .545** | .684** |
| Cirriped larvae | .523** | ns | ns | ns | ns |
| Decapod larvae | .764** | ns | -.643** | ns | -.681** |
| Gastropod veligers | .480* | ns | -.632** | ns | -.442* |
| Polychaete larvae | ns | ns | ns | ns | ns |
| Fish egg | .830** | ns | -.680** | ns | -.703** |
| Fish larvae | .717** | ns | -.558** | ns | -.747** |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
ns = not significant

## Discussion

The present study revealed the qualitative and quantitative structure of mesozooplankton in three different regions of the Southern Black Sea during two different seasons (summer and winter). Coastal marine ecosystems, like our study area, are dynamic environments influenced by meteorological events and variations in riverine and terrestrial inputs. These factors influence the quantities of inorganic nutrients and phytoplankton in the marine environment and also affect many other physicochemical properties of the marine environment [24, 25]. The sudden variations in these dynamic environments can influence the quantity, diversity, availability and seasonal cycle of mesozooplanktonic organisms living there [26]. Freshwater cladoceran species were recorded in January 2020 probably due to the positioning of the sampling station on the river plume over marine waters by the Sakarya River (Table 1). The absence of such a freshwater plankton at the Yeşilırmak River mouth is related to the location of the sampling stations out of the freshwater plume (or to a freshwater input feasible from the second river). The very high Chlorophyll-*a* concentration in July 2019 at SN01 station off the coast of Samsun Port is referable to the high eutrophication as a result of the anthropic activities (metal industry) in this region [24, 27]. Temporal and spatial variations in the qualitative and quantitative structure of marine mesozooplankton are the result of the combination of various biotic and abiotic environmental factors, including temperature, salinity, dissolved oxygen and nutrient concentrations [28]. Copepoda is the dominant component of mesozooplankton in the Black Sea coastal marine pelagic ecosystem, accounting for 62–76% of mesozooplankton abundance [29, 30]. Other studies conducted in different coastal regions of the Black Sea showed parallel findings. *A. clausi*, *P. parvus* and *O. davisae* are eurytherm copepods which are seen in all seasons in the Black Sea where they reproduce throughout the year. Detected in high quantities in plankton samples during the summer and autumn seasons, *C. ponticus* and *A. tonsa* are coastal and temperate species of the Black Sea. Defined as cold water species in the Black Sea, *C. euxinus*, *P. elongatus* and *O. similis* become concentrated in hypoxic waters in deep layers. They occur in significant abundance in surface waters exclusively during the cold season [31-35]. The seasonality of the copepod species in this study is in line with other studies of the Black Sea coast of Turkey [29, 32, 33]. Temperature is a major determinant of the presence and abundance of Cladocera in marine coastal areas [30, 36] and has an impact on seasonality and abundance by influencing their reproductive strategies and development [37]. The temporal distributions of Cladocera in the Black Sea demonstrate a significant seasonality. Temperate water cladocerans *P. avirostris*, *P. tergestina* and *E. spinifera* [38, 39] are present in the plankton of the Black Sea during summer and in early autumn [40]. The presence of *P. polyphemoides* in the Black Sea was observed almost all year round, and they were detected in high quantities during the winter-spring period [29]. Meroplankton (pelagic larvae of benthic invertebrates) provide a significant contribution to the mesozooplankton abundance and biomass in coastal waters of the Black Sea. The biodiversity and abundance of meroplankton are significant indicators to comprehend benthic communities in coastal marine waters and to understand the influences of environmental parameters on benthic communities. Larvae of Bivalvia, Gastropoda, Polychaeta and Cirripedia are the dominant meroplankton groups in the Black Sea [12, 41]. Cirripedia and Bivalvia were found in high concentrations in summer samples and in winter samples, respectively, as is also observed along the Romanian coastal waters [30]. *Noctiluca scintillans* is an omnivorous [42, 43] and opportunistic [44] dinoflagellate species that has wide range of diets (bacteria, phytoplankton, zooplankton egg and nauplii). *N. scintillans* can influence mesozooplankton abundance directly by feeding on zooplankton eggs and nauplii and indirectly by competing with mesozooplankton through food competition [45, 46]. Therefore, the Black Sea pelagic community plays a significant role [47, 48] and is called a non-fodder zooplankton component [30]. In this study, a negative correlation was found between the abundance values of *N. scintillans* and the total mesozooplankton abundance and biomass values, and the abundance values of *A. clausi*, *C. ponticus*, *P. avirostris*, *P. tergestina* and fish eggs and larvae. A positive correlation was found between the abundance value of *N. scintillans* and the abundance values of *P. parvus*, copepod nauplii and bivalve larvae. Apart from the continuous, although oscillating abundance and the presence of "perennial species", we have to pay attention to the seasonally out-bursting ones which could produce biomass accumulation and cause consequent degradation and final eutrophication. Excluding some species evidently coming from freshwater resources (thus unable to survive in marine environments), for the interpretation of differences in presence and abundance, we have to consider that some other species (such as *A. tonsa*) are typical inhabitants of more confined environments, and their presence could be due to just a derivation from confined situations (e.g. ports) of extreme abundances. Finally, coastal species commonly show the possibility to rest during adverse seasons and to dominate plankton during favourable seasons (as all the Cladocera, and *A. tonsa* and *C. ponticus* among Copepoda) [49]

## Conclusion

This study is a part of the research carried out within the scope of the ANEMONE project (Assessing the vulnerability of the Black Sea marine ecosystem to human pressures) funded by the European Union to determine the effects of riverine and human influences on the ecosystem along the Turkish coast of the Black Sea. The present study's findings provide data on the mesozooplankton structure in a marine environment located off two major rivers (Sakarya River and Yeşilırmak River) which discharge into the Black Sea, and Samsun Port. In this study, 30 marine and 6 freshwater mesozooplankton species/taxa and *N. scintillans* were identified. Copepoda revealed a high species diversity in all the research areas and Cladocera also showed a high diversification. Copepoda made significant contributions to the mesozooplankton community followed by Cladocera and the meroplanktonic components. These studies need to be planned as long-term studies to examine the influence of environmental factors on mesozooplankton community structure and to observe the regional differences in similar areas under riverine and human influence. In this context, present work is considered to constitute a basis for future studies.

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***Authors Contribution*** Authors contributed equally to the study. All authors read and approved the final manuscript.

## References

[1] Theodorou, I., Zervoudaki, S., Varkitzi, I., & Tsirtsis, G. (2023). Assessing good environmental status through mesozooplankton biodiversity: a step forward. *Journal of Plankton Research*, *45*(1), 52–64. https://doi.org/10.1093/plankt/fbac067

[2] Steinberg, D. K., & Landry, M. R. (2017). Zooplankton and the ocean carbon cycle. *The Annual Review of Marine Science*, *9*, 413–444. https://doi.org/10.1146/annurev-marine-010814-015924

[3] Kovalev, A. V., Skryabin, V. A., Zagorodnyaya, Yu. A., Niermann, U., Bingel, F., Kıdeyş, A. E., Niermann, U., & Uysal, Z. (1999). The Black Sea zooplankton: composition, spatial/temporal distribution and history of investigations. *Turkish Journal of Zoology*, *23*(2), 195–209.

[4] Dzierzbicka-Głowacka, L., Kalarus, M., & Żmijewska, M. I. (2013). Interannual variability in the population dynamics of the main mesozooplankton species in the Gulf of Gdańsk (southern Baltic Sea): Seasonal and spatial distribution. *Oceanologia*, *55*(2), 409–434. https://doi.org/10.5697/oc.55-2.409

[5] Piontkovski, S. A., Fonda-Umani, S., Stefanova, K., Kamburska, L., Olazabal, A. De. (2011). An impact of atmospheric anomalies on zooplankton communities in the Northern Adriatic and Black Seas. *International Journal of Oceans and Oceanography*, *5*(1), 53–71.

[6] Gubanova, A., Goubanova, K., Krivenko, O., Stefanova, K., Garbazey, O., Belokopytov, V., Liashko, T., & Stefanova, E. (2022). Response of the Black Sea zooplankton to the marine heatwave 2010: Case of the Sevastopol Bay. *Journal of Marine Science and Engineering*, *10*(12), 1933. https://doi.org/10.3390/jmse10121933

[7] Kovalev, A. V., Niermann, U., Melnikov, V. V., Belokopytov, V., Uysal, Z., Kıdeyş, A. E., Ünsal, M., & Altukhov, D. (1998). Long-term changes in the Black Sea zooplankton: the role of natural and antropogenic factors. In. L, Ivanov, T. Oguz (Ed), *NATO TU-Black Sea Assessment Workshop: NATO TU-Black Sea Project, Symposium on Scientific Results*, (pp. 221–234).

[8] Selifonova, J. (2000). Seasonal and long-term dynamics of the zooplankton community in Novorossiysk Bay of the Black Sea exposed to anthropogenic impact. *Acta Zoologica Bulgarica*, *52*(3), 63–74.

[9] Arashkevich, E. G., Timonin, A. G., Zatsepin, A. G., Kremenetskiy, V. V., & Drits, A. V. (2005). Effect of the rim current regime on the zooplankton distribution in the "shelf-slope-deep sea" system in the Black Sea. *Oceanology*, *45*(Suppl. 1), 149–160.

[10] Rabalais, N. N., Turner, R. E., Díaz, R. J., & Justić, D. (2009). Global change and eutrophication of coastal waters. *ICES Journal of Marine Science*, *66*(7), 1528–1537. https://doi.org/10.1093/icesjms/fsp047

[11] Bedford, J., Ostle, C., Johns, D. G., Atkinson, A., Best, M., Bresnan, E., Machairopoulou, M., Graves, C. A., Devlin, M., Milligan, A., Piotis, S., Mellor, A., Tett, P., & McQuatters-Gollop, A. (2020). Lifeform indicators reveal large-scale shifts in plankton across the North-West European shelf. *Global Change Biology, 26*(6), 3482–3497. https://doi.org/10.1111/gcb.15066

[12] Stefanova, K. (2015). Long-term shifts of the zooplankton community in the western Black Sea (Cape Galata Transect, Bulgarian Coast). *Journal of Research in Environmental and Earth Science, 2*(6), 01–10.

[13] Besiktepe, S., Kucuksezgin, F., Besiktepe, S. T., Eronat, C., Gonul, T., Terbıyık Kurt, T., Sayın, E., & Gubanova, A. (2023). Variations in copepod composition and diversity in relation to eutrophication and hydrology in İzmir Bay, Aegean Sea. *Marine Pollution Bulletin*, *197*, 115745. https://doi.org/10.1016/j.marpolbul.2023.115745.

[14] Isik, S., Dogan, E., Kalin, L., Sasal, M., & Agiralioglu, N. (2008). Effects of anthropogenic activities on the Lower Sakarya River. *Catena*, *75*(2), 172–181. https://doi.org/10.1016/j.catena.2008.06.001

[15] Şimşek, A., Türkten, H., & Bakan, G. (2022). Evaluation of water quality of the middle Black Sea region, Kızılırmak and Yeşilırmak Rivers using water quality index and statistical analysis. *The Black Sea Journal of Sciences*, *12*(2), 645–662. https://doi.org/10.31466/kfbd.1100682 (in Turkish).

[16] Yılmaz, A. (2006). The port of Samsun. *Türk Coğrafya Dergisi*, *45*, 85–100. (in Turkish).

[17] Hansen, H. P. (1999). Determination of oxygen. In K. Grasshoff, K. Kremling, M. Ehrhard (Ed). *The methods of seawater analysis*, (pp. 75–89). 3rd ed. Wiley: VCH Verlag, https://doi.org/10.1002/9783527613984.ch4

[18] Parsons, T. R., Maita, Y., & Lalli, C. M. (Ed.) (1984). *A manual of chemical and biological methods for seawater analysis*. Oxford (UK): Pergamon Press.

[19] Postel, L., Fock, H., & Hagen, W. (2000). Collecting zooplankton. In R. Harris, P. Wiebe, H.R. Skjoldal, M. Huntley (Ed). *ICES Zooplankton methodology manual*, (pp. 53–81). London (UK): Academic Press.

[20] Petipa, T. S. (1957). On average weight of the main zooplankton forms in the Black Sea. *Proceedings of Sevastopol Biological Station*, *9*, 39–57. (in Russian).

[21] Niermann, U., Kideys, A. E., Besiktep,e S., Nicolae, B., Goubanova, A., Khoroshilov, V., Mikaelyan, A., Moncheva, S., Mutlu, E., Nezlin, N., Petruanu, A., Senichkina, L., Shiganova, T. (1995). An assessment of recent Phyto and Zooplankton investigations in the Black Sea and planning for future. Report on the meeting of Marine Biologists in Erdemli, Turkey, 20 February-3 March 1995. TU-Black Sea Project, NATO Science for Stability Program. M.E.T.U., Institute of Marine Sciences, Erdemli, İçel, Turkey; p. 100.

[22] Bradford-Grieve, J. M., Markhaseva, E. L., Rocha, C. E. F., & Abiahy, B. (1999). Copepoda. In D. Boltovskoy, (Ed), *South Atlantic Zooplankton*, (pp. 869–1098). Leiden: Backhuys Publishers.

[23] Conway, D. V. P., White, R. G., Hugues-Dit-Ciles, J., Gallienne, C. P., & Robins, D. B. (Ed.) (2003). *Guide to the coastal and surface zooplankton of the south-western Indian Ocean*. Plymouth: United Kingdom.

[24] Lazăr, L., Boicenco, L., Denga, Y., Tolun, L., & Kurt, G (Ed) (2021a). *Anthropogenic pressures and impacts on the Black Sea coastal ecosystem*. CD Press: Bucharest, Romania.

[25] Lazăr, L., Boicenco, L., Moncheva, S., Denga, Y., & Atabay, H. et al. (Ed.) (2021b). *Impact of the rivers on the Black Sea Ecosystem*. CD Press: Bucharest, Romania.

[26] Calbet, A., Garrido, S., Saiz, E., Alcaraz, M., & Duarte, C. M. (2001). Annual zooplankton succession in coastal NW Mediterranean waters: the importance of the smaller size fractions. *Journal of Plankton Research*, *23*(3), 319–331. https://doi.org/10.1093/plankt/23.3.319

[27] Tan, İ., Atabay, H., Mutlu, S., Tolun, L. G., Polat Beken, S. Ç. (2023). A comparison of the surface water quality in distinct areas of the southern Black Sea coast under various pressures. *Research Square*, 1–12. https://doi.org/10.21203/rs.3.rs-3100718/v1

[28] Rekik, A., Guermazi, W., Kmiha-Megdiche, S., Sellami, I., Pagano, M., Ayadi, H., & Elloumi, J. (2023). Spatial variation of summer microphytoplankton and zooplankton communities related to environmental parameters in the coastal area of Djerba Island (Tunisia, Eastern Mediterranean). *Mediterranean Marine Science*, *24*(1), 156–172. https://doi.org/10.12681/mms.30650

[29] Üstün, F., Bat, L., & Mutlu, E. (2018). Seasonal variation and taxonomic composition of mesozooplankton in the Southern Black Sea (off Sinop) between 2005 and 2009. *Turkish Journal of Zoology*, *42*(5), 541–556. http://dx.doi.org/10.3906/zoo-1801-13

[30] Bişinicu, E., Lazăr, L., & Timofte, F. (2023a). Dynamics of zooplankton along the Romanian Black Sea coastline: Temporal variation, community structure, and environmental drivers. *Diversity*, *15*(9), 1024. https://doi.org/10.3390/d15091024

[31] Besiktepe, S. (2001). Diel vertical distribution, and herbivory of copepods in the south-western part of the Black Sea. *Journal of Marine Systems*, *28*(3–4), 281–301. https://doi.org/10.1016/S0924-7963(01)00029-X

[32] Yıldız, İ., & Feyzioğlu, A. M. (2014). Biological diversity and seasonal variation of mesozooplankton in the southeastern Black Sea coastal ecosystem. *Turkish Journal of Zoology*, *38*(2), 179–190. https://doi.org/10.3906/zoo-1304-32

[33] Üstün, F. (2019). Seasonal cycle of zooplankton abundance and biomass in Hamsilos Bay, Sinop, southern Black Sea, Turkey. *Journal of Natural History*, *53*(7–8), 365–389. https://doi.org/10.1080/00222933.2019.1592257

[34] Prusova, I. Yu., & Galagovets, E. A. (2022). Sex ratios of calanoid copepods in the northern Black Sea. *Regional Studies in Marine Science, 55,* 102576. https://doi.org/10.1016/j.rsma.2022.102576

[35] Bişinicu, E., Harcota, G. E., & Lazăr, L. (2023b). Interactions between environmental factors and the mesozooplankton community from the Romanian Black Sea waters. *Turkish Journal of Zoology*, *47*(4), 202–2015. https://doi.org/10.55730/1300-0179.3133

[36] Gülşahin, N., & Tarkan, A. N. (2012). Seasonal changes in distribution and abundance of the cladoceran species in relation to environmental factors in Gökova Bay (Muğla, Aegean Sea, Turkey). *Fresenius Environmental Bulletin*, *21*(7a), 1853–1863.

[37] Bedikoğlu, D., Yilmaz, I. N., & Demirel, N. (2022). Reproductive strategies and population characteristics of key Cladocera species in the Sea of Marmara. *Regional Studies in Marine Science*, *54*, 102450. https://doi.org/10.1016/j.rsma.2022.102450

[38] Marazzo, A., & Valentin, J. L. (2000). A report on the marine cladoceran *Evadne spinifera* Müller (Crustacea, Branchiopoda) in Guanabara Bay, Rio de Janeiro, Brazil. *Revista brasileira de Zoologia*, *17*(4), 1101–1102.

[39] Marazzo, A., & Valentin, J. L. (2001). Spatial and temporal variations of *Penilia avirostris* and *Evadne tergestina* (Crustacea, Branchiopoda) in a Tropical Bay, Brazil. *Hydrobiologia*, *445*(1–3), 133–139. https://doi.org/10.1023/A:1017592323388

[40] Lebedeva, L. P., Lukasheva, T. A., Anokhina, L. L., & Chasovnikov, V. K. (2015). Interannual variability in the zooplankton community in Golubaya Bay (Northeastern part of the Black Sea) in 2002–2012. *Oceanolog*y, *55*(3), 355–363. https://doi.org/10.1134/S0001437015030091

[41] Vereshchaka, A. L., Anokhina, L. L., Lukasheva, T. A., & Lunina, A. A. (2019). Long-term studies reveal major environmental factors driving zooplankton dynamics and periodicities in the Black Sea coastal zooplankton. *PeerJ*, *7*, e7588. https://doi.org/10.7717/peerj.7588

[42] Kirchner, M., Sahling, G., Uhlig, G., Gunkel, W., & Klings, K. W. (1996). Does the red tide-forming dinoflagellate *Noctiluca scintillans* feed on bacteria? *Sarsia*, *81*(1), 45–55. https://doi.org/10.1080/00364827.1996.10413610

[43] Mikaelyan, A. S., Malej, A., Shiganova, T. A., Turk, V., Sivkovitch, A. E., Musaeva, E. I., Kogovsek, T., & Lukasheva, T. A. (2014). Populations of the red tide forming dinoflagellate *Noctiluca scintillans* (Macartney): A comparison between the Black Sea and the northern Adriatic Sea. *Harmful Algae*, *33*, 29–40. http://dx.doi.org/10.1016/j.hal.2014.01.004

[44] Oguz, T., & Velikova, V. (2010). Abrupt transition of the northwestern Black Sea shelf ecosystem from a eutrophic to an alternative pristine state. *Marine Ecology Progress Series*, *405*, 231–242. https://doi.org/10.3354/meps08538

[45] Nikishina, A. B., Drits, A. V., Vasilyeva, Yu. V., Timonin, A. G., Solovyev, K. A., Ratkova, T. N., & Sergeeva, V. M. (2011). Role of the *Noctiluca scintillans* population in the trophic dynamics of the Black Sea plankton over the spring period. *Oceanology*, *51*(6), 1029–1039. https://doi.org/10.1134/S0001437011060129

[46] Aytan, Ü., & Şentürk, Y. (2018) Dynamics of *Noctiluca scintillans* (Macartney) Kofoid & Swezy and its contribution to mesozooplankton in the southeastern Black Sea. *Aquatic Sciences and Engineering*, *33*(3), 84–89. https://doi.org/10.26650/ASE201814

[47] Oguz, T., Malanotte-Rizzoli, P., & Ducklow, H. W. (2001). Simulations of phytoplankon seasonal cycle with multi-level and multi-layer physical-ecosystem models: the Black Sea example. *Ecological Modelling*, *144*(2–3), 295–314. https://doi.org/10.1016/S0304-3800(01)00378-7

[48] Kopuz, U., Feyzioglu, A. M., & Valente, A. (2014). An unusual red-tide event of *Noctiluca scintillans* (Macartney) in the southeastern Black Sea. *Turkish Journal of Fisheries and Aquatic Sciences*, *14*(1), 261–268. http://doi.org/10.4194/1303-2712-v14_1_28 (in Turkish)

[49] Belmonte, G., & Rubino, F. (2019). Resting cysts from coastal marine plankton. *Oceanography and Marine Biology*, *57*, 1 – 88.