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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Summer mesozooplankton community structure in a semi-enclosed bay of the Southern Black Sea

Güney Karadeniz'de yarı kapalı bir koyda yaz dönemi mesozooplankton topluluk yapısı

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Abstract: This study investigated the temporal and spatial variability of mesozooplankton community structure, abundance, biomass, and species composition in Hamsilos Bay, located in the southern Black Sea, during the summer of 2024. Zooplankton samples were collected monthly from six stations distributed throughout the bay between June and August 2024. Mesozooplankton abundance and biomass exhibited pronounced temporal and spatial variability, with generally higher values recorded at shallow inner-bay stations. Copepoda and meroplankton constituted the dominant components of the mesozooplankton community throughout the study period. In terms of abundance, *Paracalanus parvus*, *Oithona similis*, and *Acartia clausi* were the dominant species in June 2024, whereas a marked increase in the abundance of *Oithona davisae* was observed during July 2024 and August 2024. In addition, copepod early life stages represented a substantial proportion of the mesozooplankton community throughout the sampling period. Biomass distribution differed from abundance patterns and was mainly influenced by the contribution of meroplanktonic larvae and relatively large-bodied organisms. Multivariate analyses revealed significant differences in mesozooplankton community structure among sampling periods and stations. Overall, the results indicate that the summer mesozooplankton community structure in Hamsilos Bay was associated with temporal shifts in dominant species and local environmental conditions. Furthermore, the findings highlight the importance of evaluating both abundance and biomass together to achieve a more comprehensive assessment of mesozooplankton community structure.

Keywords: Species composition, Copepoda, meroplankton, abundance, biomass, Sinop

Öz: Bu çalışmada, Güney Karadeniz'de yer alan Hamsilos Koyu'nda 2024 yaz döneminde mesozooplankton topluluğunun bolluk, biyokütle, tür kompozisyonu ve komünite yapısındaki zamansal ve mekansal değişimi araştırılmıştır. Zooplankton örnekleri Haziran-Ağustos 2024 döneminde koy boyunca dağılım gösteren altı istasyondan aylık olarak toplanmıştır. Mesozooplankton bolluk ve biyokütle değerleri çalışma boyunca belirgin zamansal ve mekansal farklılık göstermiş, genel olarak koy içindeki sığ istasyonlarda daha yüksek değerler kaydedilmiştir. Copepoda ve meroplankton tüm örnekleme dönemi boyunca komünitenin baskın bileşenlerini oluşturmuştur. Bolluk bakımından Haziran 2024 tarihinde *Paracalanus parvus*, *Oithona similis* ve *Acartia clausi* öne çıkan türler olurken, Temmuz 2024 ve Ağustos 2024 tarihlerinde *Oithona davisae*'nin bolluğunda belirgin artış gözlenmiştir. Ayrıca kopepod erken yaşam evreleri çalışma boyunca komünite yapısında önemli bir paya sahip olmuştur. Biyokütle dağılımı bolluk yapısından farklılık göstermiş ve özellikle meroplanktonik larvalar ile görece büyük boyutlu organizmaların katkısıyla şekillenmiştir. Çok değişkenli analizler, mesozooplankton topluluğunun örnekleme dönemi ve istasyonlar arasında anlamlı farklılık gösterdiğini ortaya koymuştur. Genel olarak sonuçlar, Hamsilos Koyu'ndaki yaz dönemi mesozooplankton komünite yapısının baskın türlerdeki zamansal değişim ve çevresel koşullarla ilişkili olduğunu, ayrıca komünitenin değerlendirilmesinde bolluk ve biyokütle verilerinin birlikte ele alınmasının önemli olduğunu göstermektedir.

Anahtar kelimeler: Tür kompozisyonu, Copepoda, meroplankton, bolluk, biyokütle, Sinop

INTRODUCTION

Zooplankton play a crucial role in aquatic ecosystems, acting as a fundamental link in the food web by transferring energy from primary producers, such as phytoplankton, to higher trophic levels, including fish and invertebrates (Raymont, 1967; Banse, 1995; Thorpe, 2024). Their abundance and diversity are influenced by various environmental factors, including nutrient availability, temperature, and hydrological conditions, which shape community structure and dynamics (Mann and Lazier, 2006). Due to their sensitivity to environmental variability, zooplankton communities are widely used as indicators of ecosystem condition and environmental change (Ndah et al., 2022; Bisinicu and Harcota, 2025; Baiandina et al., 2026).

In coastal and semi-enclosed systems, such as bays and lagoons, zooplankton communities are particularly sensitive to both natural variability and anthropogenic influences. These environments often exhibit strong spatial gradients driven by hydrodynamics, freshwater inputs, and exchange with adjacent open waters, leading to pronounced differences in environmental conditions over relatively short distances (Cloern et al., 2016; Johnston et al., 2022). Such gradients can significantly affect zooplankton distribution, biomass, and species composition, making these systems suitable for studying ecosystem structure and functioning. In addition, seasonal variability, particularly during summer months when temperature stratification and biological production are intensified, can further influence zooplankton community dynamics (Mikaelyan et al., 2021; Bişinicu et al., 2024).

Beyond their trophic role, zooplankton also contribute to nutrient cycling and energy flow in aquatic ecosystems

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(Ratnarajah et al., 2023). Variations in their community structure can reflect changes in water quality and environmental conditions, providing insights into ecological status and the impacts of external pressures such as climate change and human activities (Lomartire et al., 2021).

Hamsilos Bay is a unique pelagic ecosystem along the southern Black Sea coast due to its semi-enclosed structure, preserved ecological characteristics, and its openness to coastal-offshore interactions. The area exhibits high biological diversity in terms of zooplankton (Üstün, 2019; Üstün and Birinci Özdemir, 2019; Üstün, 2025). Previous studies have revealed not only this diversity but also the presence of new species records (Suárez-Morales and Üstün, 2018) and the establishment of non-indigenous species in the area (Üstün et al., 2024a). In addition, Hamsilos serves as an important habitat for the early life stages of fish (Uygun and Üstün, 2024). With these characteristics, Hamsilos Bay represents an important reference area for biodiversity and ecosystem monitoring studies. In this context, the present study aims to investigate mesozooplankton abundance, biomass, species diversity, and their relationships with environmental variables in Hamsilos Bay (southern Black Sea), a semi-enclosed coastal system. The findings are expected to contribute to a better understanding of biodiversity patterns and ecological status in the region, and to provide baseline information for future monitoring and management efforts.

MATERIALS AND METHODS

The study was conducted in Hamsilos Bay, located on the southern Black Sea coast of Türkiye. Zooplankton sampling was carried out during the summer period (13 June, 12 July, and 13 August 2024) at six stations distributed throughout the bay. The geographic coordinates of the stations and vertical sampling depths are provided in Table 1 and Figure 1. All sampling operations were performed using a rented fishing vessel.

Table 1. Geographic coordinates and vertical sampling depths of the stations

Station	Latitude (N)	Longitude (E)	Station Depth (m)	Sampling Depth (m)
1	42°03'44"	35°03'09"	30	28
2	42°04'1"	35°03'3"	22	20
3	42°03'46"	35°02'47"	14	12
4	42°03'41"	35°02'37"	11	9
5	42°03'37"	35°02'37"	5	4
6	42°03'37"	35°02'32"	3	2

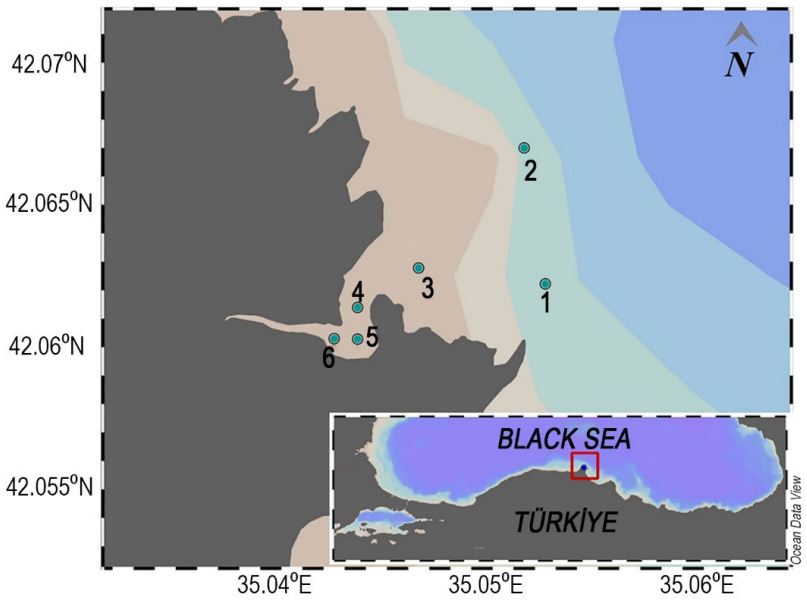

Figure 1. Location of the six sampling stations in the study area

Surface seawater temperature (°C), salinity, and dissolved oxygen (mg L^{-1}) were measured in situ at each station using a portable multiparameter probe (YSI Professional Plus).

Zooplankton samples were collected by vertical hauls using a plankton net with a 50 cm mouth diameter and 112 µm mesh size. At each station, a single tow was conducted from the maximum sampling depth to the sea surface. The filtered water volume (m^3) was calculated as the product of the net mouth area and the vertical sampling depth.

Immediately after collection, the samples were preserved in borax-buffered formaldehyde solution at a final concentration of 4% for subsequent quantitative and qualitative analyses.

In the laboratory, each sample was homogenized and reduced to an appropriate final volume depending on the abundance of organisms in the sample. Samples with low organism abundance were examined in their entirety. For samples with high organism abundance, the final volume was adjusted to 50 mL, and two 1 mL subsamples (4% of the final sample volume) were taken using a Stempel pipette. The

subsamples were examined using a stereomicroscope (SOIF SZM45 B2/L) and a zooplankton counting chamber to determine species composition and abundance. Counts obtained from two subsamples were averaged and extrapolated to the total sample volume. To ensure accurate representation of the community, the entire 50 mL sample was additionally screened for rare and large organisms (e.g., Chaetognatha and decapod larvae) that might not appear in the subsamples.

Zooplankton taxa were identified to species level whenever possible (e.g., Copepoda, Cladocera, Appendicularia and Chaetognatha), while other groups were identified to higher taxonomic levels. Taxonomic identification followed standard references (Bradford-Grieve et al., 1999; Conway et al., 2003), and nomenclature was verified according to the World Register of Marine Species (WoRMS). In this study, the term 'copepod early life stages' encompasses copepod eggs and nauplii.

Zooplankton abundance was expressed as individuals per cubic meter (ind. m^{-3}), calculated by extrapolating counts obtained from subsamples to the total sample volume and the filtered water volume. Biomass values (mg m^{-3}) were estimated based on individual wet weights derived from literature sources (Petipa, 1957; Niermann et al., 1995).

Spearman's rank correlation analysis was performed to assess the relationships between environmental variables (temperature, salinity, and dissolved oxygen), the abundance of *Noctiluca scintillans*, and mesozooplankton species/groups abundance. The analysis was conducted using R software 4.5v (R Core Team, 2026).

To evaluate temporal and spatial variations in mesozooplankton community structure, diversity indices and multivariate statistical analyses were applied. Mesozooplankton community structure was assessed using the Shannon-Weaver diversity index (H'), Pielou's evenness index (J'), and the Bray-Curtis similarity index. Abundance data were $\log_{10}(x+1)$ transformed prior to analyses to reduce the influence of dominant taxa. The Bray-Curtis similarity matrix derived from the transformed abundance data was used for non-metric multidimensional scaling (nMDS) and hierarchical cluster analysis (CLUSTER) (Clarke, 1993; McCune et al., 2002). Analysis of similarities (ANOSIM) was performed to determine whether the differences in community structure among sampling periods and stations were statistically significant (Clarke, 1993). In addition, similarity percentage analysis (SIMPER) was conducted to identify the taxa contributing most to the observed similarities and dissimilarities within the mesozooplankton community (Clarke and Warwick, 2001). All identified taxa, including rare species, were included in the analyses. All multivariate analyses were carried out using PRIMER v7 software (Clarke and Gorley, 2015). The "psych" package (Revelle, 2026) was used for Spearman correlation analysis, the "corrplot" package (Wei and Simko, 2024) was used for correlation matrix visualization, and the "openxlsx" package (Schauberger and Walker, 2025) was used for data export.

RESULTS

Surface seawater temperature, salinity, and dissolved oxygen values exhibited clear temporal variation throughout the sampling period, as shown in Figure 2. Temperature values ranged between 22.4°C and 27.3°C, with a mean of 24.4±0.5°C. While temperature values remained relatively similar among stations in June 2024 and July 2024, higher values were recorded in August 2024. Surface seawater salinity values varied within a narrower range compared to temperature, ranging between 16.71 and 17.61, with a mean salinity of 17.3±0.1. Salinity showed a slight increase from June 2024 to July 2024 and then remained relatively stable across stations in August 2024. Surface seawater dissolved oxygen concentrations ranged from 5.22mg L^{-1} to 6.92 mg L^{-1}, with a mean value of 5.94±0.1mg L^{-1}. Dissolved oxygen concentrations were higher in June 2024 and July 2024, whereas lower were observed in August 2024 (Figure 2).

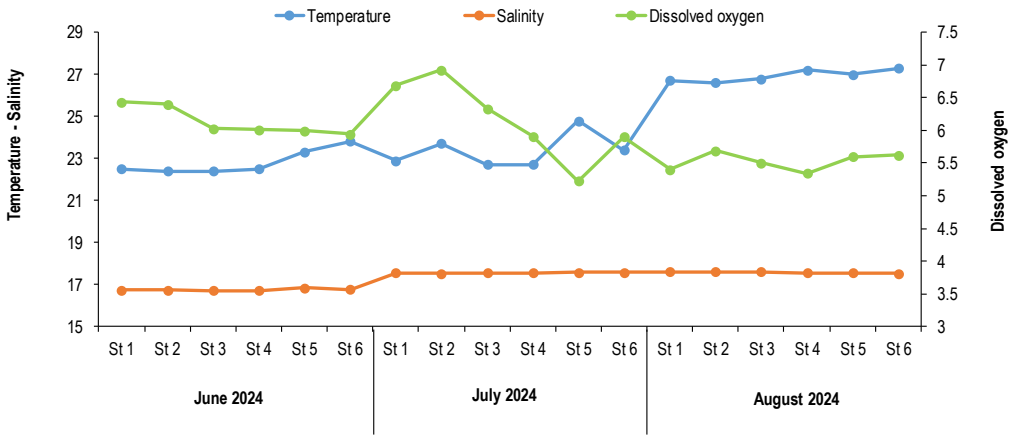

Figure 2. Temporal and spatial variation of surface seawater temperature (°C), salinity, and dissolved oxygen (mg L^{-1}) across stations from June to August 2024

Mesozooplankton abundance and biomass exhibited both temporal and spatial variability throughout the study period. Monthly mean abundance and biomass values are presented in Table 2, while their spatial variations among stations are shown in Figure 3a, b. In general, both abundance and biomass were higher at the shallower inner-bay stations and lower at the deeper outer-bay stations (Figure 3a, b).

The mesozooplankton community throughout the study was primarily characterized by the dominance of Copepoda and meroplankton groups (Figure 3c, d). Both groups constituted a substantial proportion of the total abundance during all sampling periods. In contrast, the Diplostraca group showed a more pronounced contribution, particularly in June 2024 and August 2024 (Figure 3c, d).

The copepod community during the summer period was mainly shaped by the high contribution of copepod early life stages and small-bodied species (Figure 4). *Paracalanus parvus*, *Oithona similis*, and *Acartia clausi* were the dominant species in June 2024, whereas a marked increase in the abundance of *Oithona davisae* was observed during July 2024 and August 2024. Copepod early life stages also exhibited consistently high abundance values throughout the entire study period (Figure 4).

Among the Diplostraca species, *Pleopis polyphemoides* was characterized by high abundance values in June 2024, whereas *Evadne spinifera* and *Penilia avirostris* exhibited higher abundances in August 2024 (Figure 4). The contribution of meroplankton to total mesozooplankton abundance was particularly high at the shallow inner-bay stations (Figure 3a), mainly associated with the high abundance of bivalve and gastropod larvae (Figure 4).

Oikopleura dioica exhibited higher abundance particularly at the deeper outer-bay stations during June 2024 and July 2024; however, its contribution to total abundance remained limited (Figure 3a, c). *Parasagitta setosa* was recorded at relatively low abundance throughout the study period, although higher values were observed during July 2024 and August 2024 (Figure 3a, c).

Biomass distribution showed a different pattern from that observed for abundance (Figure 3b, d). Meroplankton constituted the major contribution to total biomass, mainly associated with the high biomass values of bivalve, gastropod, and polychaete larvae (Figure 4). Copepods represented the second most important biomass group, with *Centropages ponticus*, a relatively large-bodied copepod species, together with *A. clausi*, *O. davisae*, and *P. parvus* contributing substantially to total biomass. Although the Diplostraca group generally exhibited a lower contribution to biomass, *P. polyphemoides* and *P. avirostris*, which is relatively large-bodied among marine diplostracan species, were characterized by comparatively higher biomass values in June 2024 and August 2024 (Figure 4).

Table 2. Monthly mean (± SE) abundance (ind. m^{-3}) and biomass (mg m^{-3}) values of mesozooplankton taxa and *Noctiluca scintillans* during summer 2024 (Values are presented as mean ± standard error (SE) across stations)

		June 2024		July 2024		August 2024	
		Abundance	**Biomass**	**Abundance**	**Biomass**	**Abundance**	**Biomass**
Appendicularia	*Oikopleura dioica*	134±58.7	1.2±0.5	88.5±43	0.6±0.4	35±23.5	0.3±0.2
Chaetognatha	*Parasagitta setosa*	6.4±2.3	0.2±0.1	14.3±2.1	0.6±0.2	17±5.8	1±0.3
Copepoda	*Acartia clausi*	186.4±72.5	0.9±0.4	409.2±93.4	2.0±0.5	75.6±17.8	1±0.4
	Calanus euxinus	2.9±1.7	0.1±0.05				
	Centropages ponticus	10.5±7	0.4±0.3	54±22	0.4±0.1	17±3.6	0.2±0.03
	Oithona davisae	39±13.6	0.1±0.04	796.6±164.3	2.2±0.4	1229.5±224	3.4±0.7
	Oithona similis	211.2±84.8	0.7±0.3	132.8±43.4	0.5±0.2	8.8±4.6	0.03±0.02
	Paracalanus parvus	305.6±127	1.9±0.9	335.1±66.6	2.1±0.5	41.1±19.8	0.3±0.1
	Pseudocalanus elongatus	25.7±15.4	0.5±0.2	0.8±0.7	0.005±0.003	0.8±0.8	0.04±0.04
	Copepod early life stages	806.3±344	0.8±0.3	3161.5±2373.8	3.1±2.3	803±294	0.8±0.3
Diplostraca	*Evadne spinifera*			8.8±4.2	0.04±0.02	149.8±80.3	0.6±0.3
	Penilia avirostris	1.0±0.8	0.03±0.02	19.8±5.7	0.6±0.2	125.4±70.1	3.5±2
	Pleopis polyphemoides	391.8±81	3.5±0.7	29.9±8.5	0.3±0.1		
	Pseudevadne tergestina	5.3±4	0.02±0.02	10.5±2.7	0.04±0.01	1.1±0.4	0.004±0.002
Meroplankton	Actinotroch larvae	0.2±0.1	0.003±0.002	0.5±0.4	0.01±0.01	0.4±0.3	0.007±0.005
	Ascidian larvae			0.1±0.1	0.0003±0.0003		
	Bivalve larvae	1363±451	6.8±2.3	907.0±300.4	4.5±1.5	791.7±171	4±0.9
	Bryozoan larvae (Cyphonautes)					0.3±0.3	
	Cephalochordate larvae (*Branchiostoma*)	0.03±0.03					
	Cirripedia nauplii	179±80	2.9±1.3	77.6±29.0	1.5±0.5	27.9±11.3	0.7±0.3
	Decapod larvae	2.6±0.9	0.2±0.1	6.6±2.5	0.4±0.2	2.8±0.5	0.2±0.03
	Gastropod larvae	462.4±298	5.0±3.2	115.4±57.3	1.3±0.6	79.2±32.4	0.9±0.4
	Isopod larvae (*Microniscus*)			0.02±0.02	0.001±0.001	0.5±0.3	0.02±0.01
	Polychaete larvae	77.8±26.8	3.0±1.0	138.7±74.5	5.3±2.8	58.8±30.7	2.2±1.2
Dinoflagellata	*Noctiluca scintillans*	2468±1124	217.2±98.9	156.3±62.6	13.8±5.5	74±29.4	6.5±2.6

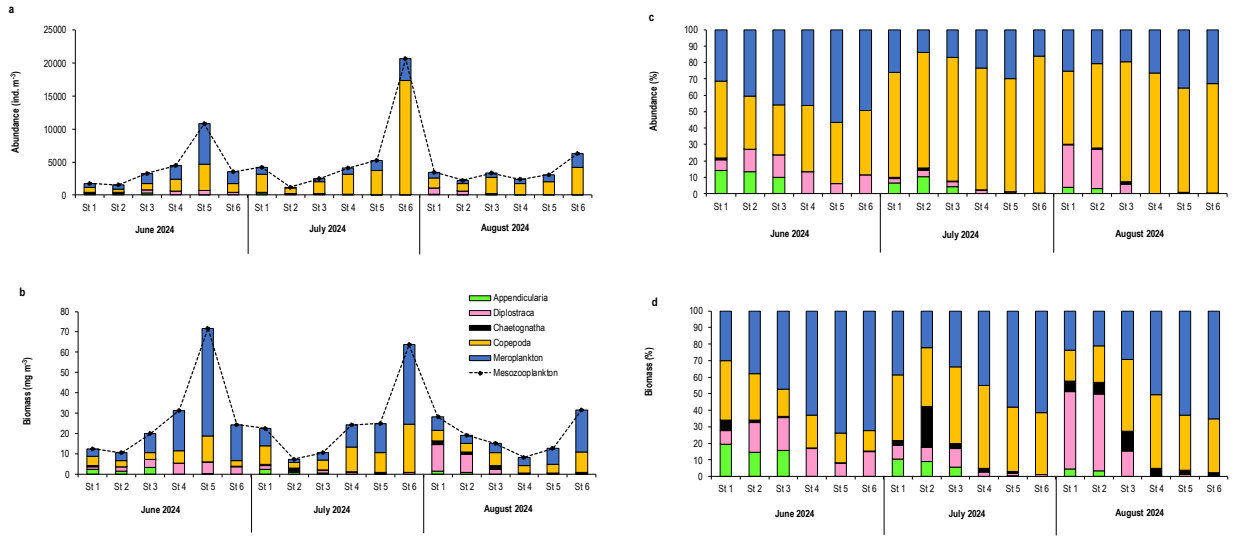

Figure 3. Temporal and spatial variation in abundance and biomass of mesozooplankton groups (a, b) and their percentage contributions (c, d) across stations from June to August 2024

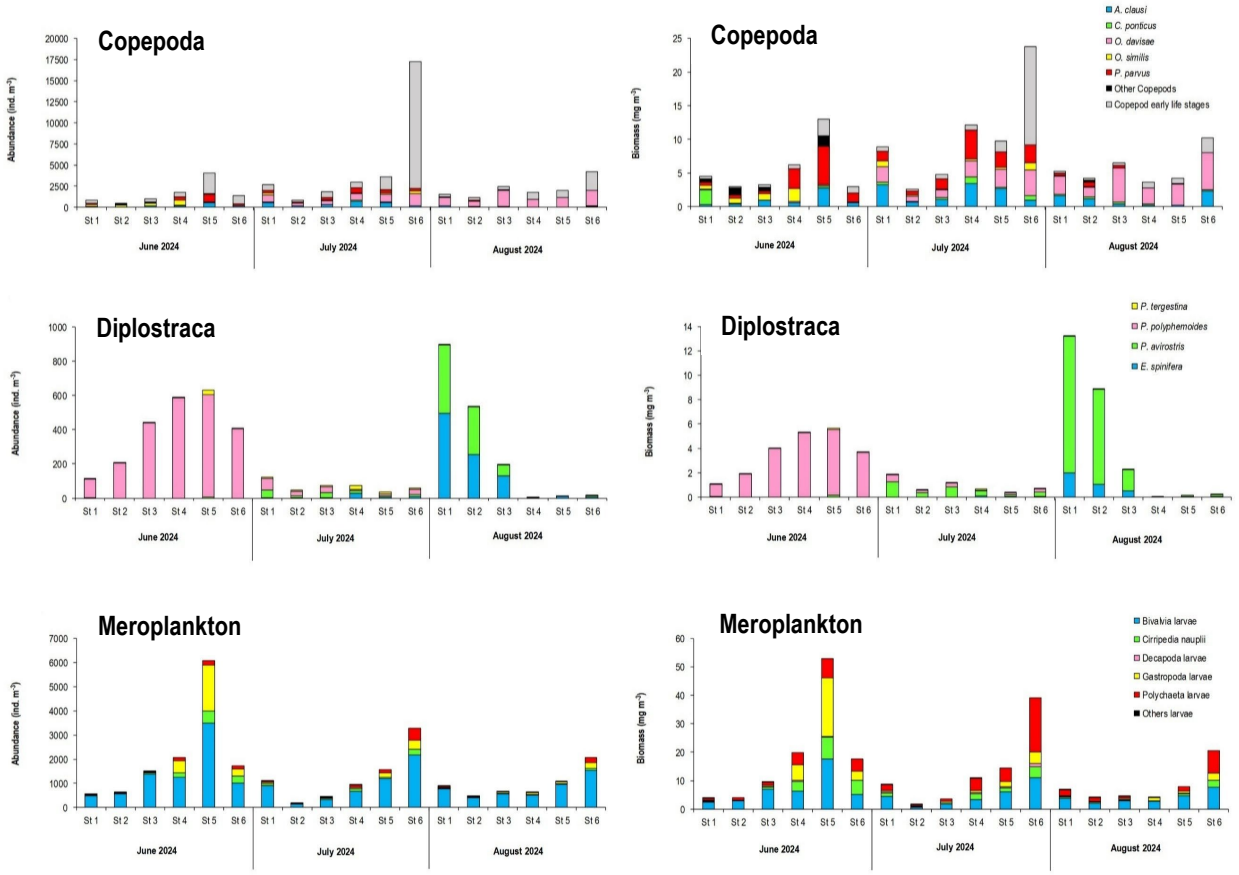

Figure 4. Temporal and spatial variation of abundance (ind. m^{-3}) and biomass (mg m^{-3}) of Copepoda and Diplostraca species and meroplanktonic groups across stations from June to August 2024. Other copepods: *Calanus euxinus* and *Pseudocalanus elongatus*; Other larvae: Actinotroch larvae, Ascidian larvae, Cephalochordate larvae (*Branchiostoma*), Bryozoan larvae (*Cyphonautes*), and Isopod larvae (*Microniscus*)

Total number of taxa, diversity, and evenness indices varied among stations and sampling months (Figure 5). Total number of taxa (S) values were generally lower at the shallow inner-bay stations and higher at the deeper outer-bay stations. The lowest diversity and evenness index values were recorded at the shallowest station (St 6) during July 2024, when copepod early life stages exhibited remarkably high abundance. Similarly, low diversity and evenness values were observed at the shallow stations (St 3-St 6) in August 2024, mainly associated with the high abundances of *O. davisae*, bivalve larvae, and copepod early life stages. In contrast, relatively higher diversity and evenness values were particularly recorded at the deeper outer-bay stations (St 1 and St 2) during July 2024 (Figure 5).

Date-Station	Total Number of Taxa (S)	Pielou's Evenness Index (J')	Shannon-Weaver Index (H')
June 24-St 1	19	0,71	3,01
June 24-St 2	18	0,66	2,76
June 24-St 3	17	0,65	2,67
June 24-St 4	15	0,76	2,98
June 24-St 5	16	0,67	2,68
June 24-St 6	13	0,72	2,67
July 24-St 1	19	0,73	3,09
July 24-St 2	20	0,72	3,12
July 24-St 3	18	0,71	2,94
July 24-St 4	18	0,72	3,00
July 24-St 5	17	0,67	2,75
July 24-St 6	16	0,39	1,54
August 24-St 1	18	0,68	2,84
August 24-St 2	19	0,72	3,07
August 24-St 3	18	0,50	2,10
August 24-St 4	13	0,51	1,90
August 24-St 5	13	0,54	2,01
August 24-St 6	13	0,58	2,14

Figure 5. Temporal and spatial variation in mesozooplankton biodiversity indices across stations from June to August 2024

CLUSTER and nMDS analyses revealed clear temporal and spatial differences in the mesozooplankton community structure (Figure 6). However, the cluster dendrogram indicated that the overall community remained highly similar (>70%) throughout the summer, with differences primarily driven by shifts in the relative abundances of dominant taxa rather than species composition (Table 2). While the June 2024 samples were separated between inner-bay and outer-bay stations, most of the July 2024 and August 2024 samples were grouped more closely together. The shallow inner-bay stations formed a more distinct group in August 2024. The low stress value (Stress=0.09) indicated that the ordination reliably represented the similarity relationships among samples. ANOSIM analysis further demonstrated that the differences among groups were statistically significant (Global R=0.837, p<0.001).

According to the SIMPER analysis, the taxa contributing most to the dissimilarities among groups were *O. dioica*, *O. similis*, *O. davisae*, *P. avirostris*, *P. polyphemoides*, *P. parvus*, and *E. spinifera*. In the June 2024 groups, bivalve larvae, *O. dioica*, *O. similis*, copepod early life stages, and *P. polyphemoides* showed relatively higher contributions, whereas *O. davisae*, copepod early life stages, and bivalve larvae contributed more strongly to the July 2024 and August 2024 samples.

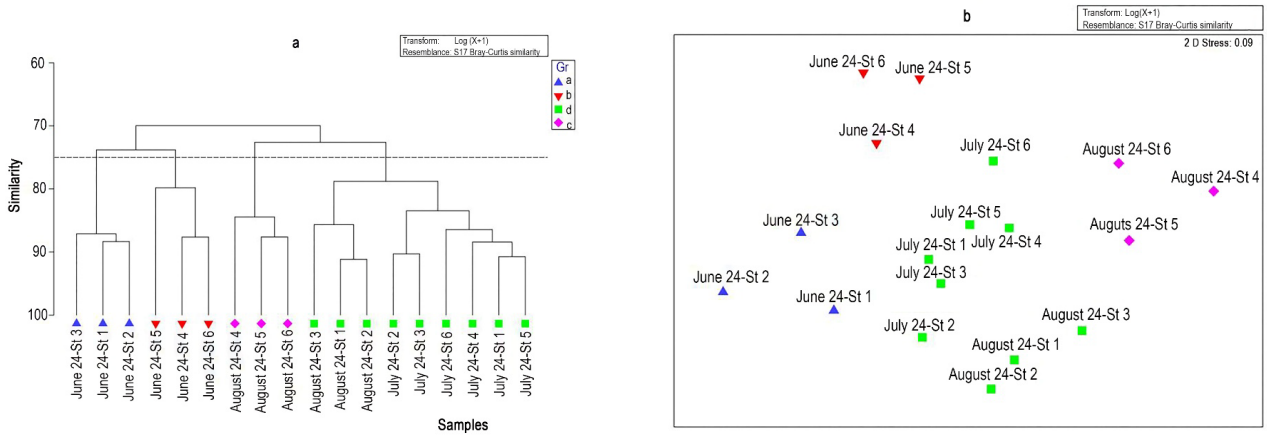

Figure 6. Cluster analysis (a) and nMDS ordination (b) based on log-transformed mesozooplankton abundance data using Bray-Curtis similarity across stations from June to August 2024

Spearman correlation analysis revealed significant relationships between several mesozooplankton taxa/groups and environmental variables during the summer period (Figure 7). In particular, Appendicularia, *P. polyphemoides*, and *O. similis* showed positive correlations with dissolved oxygen and *Noctiluca scintillans*, but negative correlations with temperature. In contrast, *O. davisae* was negatively correlated with dissolved oxygen and *N. scintillans*, while showing positive correlations with temperature and salinity (Figure 7).

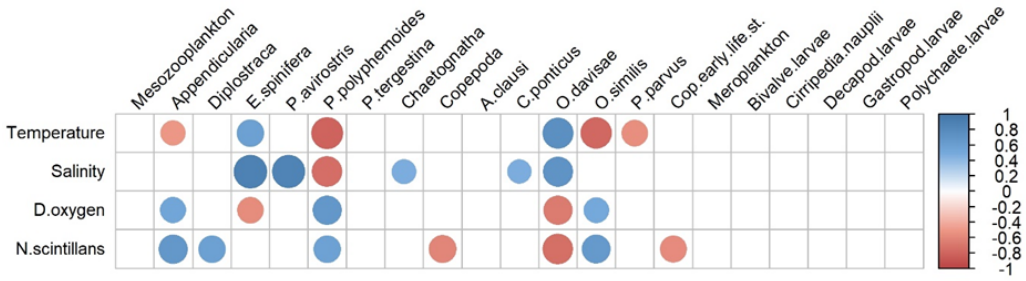

Figure 7. Spearman rank correlation coefficients between environmental variables, *Noctiluca scintillans*, and mesozooplankton species/groups. Only significant correlations are shown. Blue circles indicate positive correlations and red circles indicate negative correlations; circle size and color intensity represent correlation strength.

DISCUSSION

The present study demonstrated pronounced temporal and spatial structuring of the mesozooplankton community in Hamsilos Bay during the summer of 2024. In particular, the differences observed between the shallow inner-bay stations and the deeper stations located closer to the outer bay suggest that the spatial structure of the mesozooplankton community during the study period was associated not only with species composition, but also with the relative abundances and size structure of dominant organisms. This spatial differentiation, particularly evident during June and August, likely reflects the natural bathymetric gradient from the shallow inner bay toward the deeper outer bay, together with differences in water exchange, benthic-pelagic coupling, and local hydrographic conditions (Arashkevich et al., 2014; Üstün et al., 2026). Because the vertical extent of the sampled water column varied naturally with station depth, this aspect should also be considered when interpreting quantitative differences between shallow and deeper stations. Conversely, despite these spatial gradients, the overall mesozooplankton community maintained a high structural similarity (>70%) throughout the study period. This was most notable in July, where high spatial homogeneity was observed across all stations (clustering into a single group). This bay-wide homogenization may be associated with the relatively similar environmental conditions observed across stations during mid-summer and the widespread dominance of a few copepod taxa, primarily *Acartia clausi* and *Oithona davisae*. Similar homogenization patterns, driven by the absolute dominance of a few opportunistic species during summer, have been previously reported for the coastal waters of the Black Sea (Üstün, 2019; Bişinicu et al., 2023; Üstün et al., 2024a, 2024b, 2026). This widespread dominance of core taxa likely obscured the local spatial gradients within the bay during mid-summer.

Throughout the study, abundance values were generally higher at the shallow inner-bay stations, whereas biomass exhibited a more heterogeneous distribution among stations, indicating that abundance and biomass based community structures may differ considerably within the zooplankton community. The higher abundance at the shallow inner-bay stations was largely associated with the high numerical contribution of copepod early life stages and meroplanktonic larvae. The sheltered, semi-enclosed morphology of the inner bay may be associated with relatively restricted water exchange and may favor the local retention of these small planktonic stages. Local hydrodynamic processes can influence larval transport and retention in coastal environments, thereby contributing to spatial variability in larval abundance (White et al., 2019). In addition, the proximity of shallow benthic habitats may provide a local source of meroplanktonic larvae, further contributing to the high numerical abundance observed in the inner bay. Similar spatial patterns of higher meroplankton abundance in shallow or coastal areas have previously been reported in Hamsilos Bay and along the southern Black Sea coast (Üstün, 2019; Üstün et al., 2026). Although local circulation and water exchange were not directly measured, these processes may have contributed to the observed spatial differences in community structure. In particular, copepod early life stages, small cyclopoid copepods, and some meroplanktonic larvae contributed substantially to numerical abundance but had a relatively limited contribution to total biomass. In contrast, larger-bodied organisms, particularly *Centropages ponticus* and *Parasagitta setosa*, exerted a more pronounced influence on biomass despite their comparatively lower abundance values. These findings suggest that organism size structure may play an important role in shaping the divergence between abundance and biomass distributions within zooplankton communities. Similarly, several studies conducted in pelagic ecosystems have demonstrated that abundance and biomass based community structures may differ considerably, and that evaluating zooplankton communities solely on the basis of numerical abundance may not fully reflect overall community structure (Thompson et al., 2013; de Figueiredo et al., 2025). The use of a 112 µm mesh net should also be considered when

interpreting the abundance patterns observed in the present study. Mesh size can substantially influence the retention of small-bodied zooplankton and early developmental stages, with finer meshes generally yielding higher abundance estimates for organisms smaller than 1 mm, including copepod nauplii and early copepodite stages (Tseng et al., 2011; Altukhov et al., 2015). In the Black Sea, direct intercomparison of nets with mesh sizes ranging from 100 to 200 µm demonstrated that total abundance decreased with increasing mesh size, largely because finer meshes retained greater numbers of small individuals, whereas total biomass did not differ significantly among nets (Altukhov et al., 2015). Accordingly, the high numerical contribution of copepod early life stages observed in the present study may partly reflect the more efficient retention of small size fractions by the 112 µm mesh. This mesh-size effect should therefore be considered when comparing absolute abundance values and the relative contribution of small-bodied groups with previous Black Sea studies using coarser mesh sizes.

During the summer study period, the higher biodiversity and evenness indices observed at the deeper outer-bay stations (St 1-3) were consistent with a relatively stable pelagic environment influenced by the open Black Sea. In contrast, the shallow inner-bay stations (St 4-6) exhibited lower diversity and sharp declines in evenness throughout the summer, indicating that the observed diversity patterns also varied along the natural bathymetric gradient of the bay. Such reduction is a typical feature of semi-enclosed coastal ecosystems, where restricted water exchange promotes the rapid increase of opportunistic taxa (Arashkevich et al., 2014; Üstün, 2019; Bişinicu et al., 2023). This decrease in diversity in the inner bay was primarily associated with the high numerical dominance of copepod early life stages throughout the summer, accompanied by high abundances of *Paracalanus parvus* in June and *Oithona davisae* in July and August. The severe decline in community evenness due to the overwhelming numerical dominance of a few highly tolerant coastal species is a well-documented pattern in shallow environments of the Black Sea (Svetlichny et al., 2016; Yildiz and Feyzioğlu, 2020; Üstün et al., 2024b).

The dominance of Copepoda as a major component of the mesozooplankton throughout the sampling period is consistent with the general dominance of copepods in marine pelagic systems (Wootton and Castellani, 2017). Similarly, previous studies conducted in different coastal regions of the Black Sea have reported Copepoda as one of the dominant components of the mesozooplankton community (Bişinicu et al., 2023; Üstün et al., 2024b). In the June samples, representing the early summer period, the prominence of *Paracalanus parvus*, *Acartia clausi*, and *Oithona similis* within the mesozooplankton community suggests that coastal copepod assemblages may respond sensitively to environmental conditions over short temporal scales (Üstün, 2019; Gubanova et al., 2022; İşinibilir et al., 2024). The marked increase in *Oithona davisae* during July and August may be related to the ability of this cyclopoid copepod to tolerate high temperatures and reach high abundances under coastal environmental conditions. A previous study in Hamsilos Bay showed that the non-indigenous *O. davisae* has successfully established a persistent population in the bay, reaching high abundances particularly during the summer-autumn period, with abundance positively associated with temperature (Üstün et al., 2024a). Similarly, in the southeastern Black Sea, the abundance of this species was shown to be higher in coastal areas than offshore waters and to increase particularly during the summer-autumn period (Yildiz and Feyzioğlu, 2020). This pattern is also consistent with the thermophilic character of *O. davisae* and its capacity for rapid population development at elevated temperatures (Hubareva and Svetlichny, 2016; Svetlichny et al., 2016). Long-term observations from the Black Sea further showed that *O. davisae* responded positively to elevated summer temperatures, with its biomass being strongly associated with warming of the upper mixed layer during July-August (Anninsky et al., 2025). Accordingly, the positive correlation detected between *O. davisae* and temperature in the present study may be considered a reflection of this species' well-known thermophilic tendency as the summer season progresses. Beyond its increasing abundance, *O. davisae* has become an important component of the Black Sea pelagic food web, serving as a frequent prey item for the invasive ctenophore *Mnemiopsis leidyi*, particularly in coastal areas where the copepod reaches high abundances (Finenko et al., 2026).

The higher abundance of *Oikopleura dioica*, particularly at the deeper stations located closer to the outer bay, suggests that the bathymetric gradient, together with small-scale hydrographic differences within Hamsilos Bay may influence the distribution of appendicularians. This species, which can occur throughout the year in the Black Sea, is known to increase markedly during spring-early summer and to play an important role in the pelagic food web by efficiently filtering small particles and bacteria (Shiganova, 2005). Moreover, size-fractionated chlorophyll-*a* measurements from the coastal Black Sea have shown that picoplankton contribute substantially to total phytoplankton biomass during summer, accounting for up to 50% in surface chlorophyll-*a* (Agirbas et al., 2017). This seasonal increase in small-sized phytoplankton is consistent with the feeding preferences of appendicularians. Owing to their short generation times, high filtration capacities, and ability to feed on pico and nanoplankton sized particles, appendicularians can exhibit rapid population changes over short temporal scales in pelagic systems (Kodama et al., 2018; Li et al., 2026). Accordingly, the observed negative correlation of Appendicularia with temperature, alongside its positive association with dissolved oxygen and *Noctiluca scintillans*, likely reflects early-summer affinities and temporal overlaps in their feeding environments. A similarly strong temporal association between *O. dioica* and *N. scintillans* during summer population peaks has also been documented in the coastal Adriatic Sea (Vukanić et al., 2025).

Parasagitta setosa was represented by relatively low abundance and biomass values throughout the study, and its contribution to total mesozooplankton biomass remained limited. Previous studies in the Black Sea have reported that juvenile individuals of *P. setosa* become more prominent in the upper water layers during the summer period, whereas adults may exhibit a broader vertical distribution (Niermann et al., 1998; Besiktepe and Unsal, 2000). In addition, the reproductive period of the species is known to intensify during summer-autumn, during which small-sized individuals are recruited into the population (Besiktepe and Unsal, 2000; Üstün, 2022). In the present study, the size distribution of *P. setosa* ranged between 0.5-1 mm and 7-8 mm, with the majority of individuals concentrated within the 1-2 mm and 2-3 mm size classes. Considering the shallow and semi-enclosed structure of Hamsilos Bay, the low biomass contribution of the species is likely associated with both its low abundance and the dominance of small-sized individuals within the population.

The distribution of Diplostraca exhibited pronounced temporal variability throughout the summer period. While *Pleopis polyphemoides* was represented by higher abundance values during the early summer period, warm-water species such as *Penilia avirostris* and *Evadne spinifera* became increasingly prominent as summer progressed. This shift indicates that the dominant species composition of the diplostracan community can vary substantially throughout the summer period and that different species may respond differently to temperature changes. The greater prominence of *P. polyphemoides* during June 2024 may be associated with the distributional characteristics of the species under relatively lower temperature conditions. In contrast, the increase of *P. avirostris* and *E. spinifera* during mid-summer is consistent with the thermophilic nature of these species, which are capable of reaching high abundances in warm surface waters. Previous studies conducted in the Black Sea have similarly reported that warm-water diplostraceans, particularly *P. avirostris* and *E. spinifera*, can attain high abundance values during the summer and early autumn periods, and that temperature plays a major role in shaping the temporal variability of diplostracan communities (Üstün et al., 2018; Yildiz, 2025; Bisinicu and Lazar, 2026). In addition, marine diplostraceans are known to rapidly reach high abundances in coastal systems owing to their short generation times, parthenogenetic reproductive strategies, and life-history characteristics that enable them to respond quickly to favourable surface conditions (Üstün, 2025).

Meroplankton has been reported as one of the major components of mesozooplankton communities in the coastal waters of the Black Sea, with larvae of Bivalvia, Gastropoda, Polychaeta, and Cirripedia frequently representing dominant groups (Üstün et al., 2018; Lebedeva et al., 2015; Bişinicu et al., 2023). The distribution and abundance of meroplankton are known to be shaped by the combined effects of species-specific reproductive timing, the distribution of benthic adult populations, and local hydrodynamic processes (Pineda et al., 2007). In the present study, the higher meroplankton abundance observed particularly at the shallow inner-bay stations highlights the potential influence of the shallow-water conditions and enhanced benthic-pelagic coupling in structuring communities within semi-enclosed bay systems. Similarly, in Ambon Bay, meroplankton abundance was reported to be higher in the inner bay compared to outer bay areas, a pattern associated with the distribution of benthic habitats and restricted water exchange/advection processes (Ruli et al., 2026). The high meroplankton abundance observed in Hamsilos Bay may likewise be related to the retention of benthic-derived larvae within inner-bay areas and the influence of limited water exchange on community structure.

CONCLUSION

This study revealed pronounced temporal and spatial variability in the mesozooplankton community of Hamsilos Bay, Sinop during the summer period (June-August 2024). Community structure differed clearly between the sheltered inner-bay stations and the outer stations influenced by the open waters of the Black Sea. Although these spatial patterns may be associated with local environmental conditions and depth-related differences, the available environmental dataset was not sufficient to directly evaluate these relationships. However, it should be noted that the environmental dataset in the present study was limited to monthly surface measurements of temperature, salinity, and dissolved oxygen. Consequently, the study does not allow definitive assessment of the relative influence of individual hydrographic variables on mesozooplankton community dynamics. Future studies incorporating higher-frequency sampling together with detailed vertical hydrographic profiling and additional environmental variables (e.g., chlorophyll-a and nutrient concentrations) would provide a more comprehensive understanding of the environmental drivers of community structure in this semi-enclosed coastal system.

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AUTHORSHIP CONTRIBUTIONS

Funda Üstün: Conceptualization, Investigation, Data curation, Visualization, Writing-original draft. Orçin Uygun: Conceptualization, Investigation, Formal analysis, Writing-review & editing.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ETHICAL APPROVAL

No specific ethical approval was required for this study.

DECLARATION OF AI USE

Artificial intelligence (AI)-assisted tools, including ChatGPT (OpenAI), were used to improve the language, readability, and grammatical structure of the manuscript. The authors take full responsibility for the scientific content, interpretations, and conclusions presented in this study.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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