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Macrozoobenthic Diversity and Environmental Parameters along the Karasu Coast, Southwest Black Sea

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Research Article

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Abstract

The distribution of macrozoobenthic fauna and the physicochemical properties of surface water along the Karasu coastline of Sakarya province in the southwest of the Black Sea (Türkiye) were investigated. Sediment samples were collected from 15 stations between the mouths of Sakarya River and Küçükboğaz Stream using the Ekman grab method, and the diversity of benthic organisms was evaluated using Shannon-Weaver Diversity Index and Margalef's Species Richness Index. Physicochemical properties of water such as pH, conductivity, salinity, temperature, dissolved oxygen and oxygen saturation were also measured. The effects of these parameters on the distribution of benthic species were examined, and eight different benthic species were identified. *Donax* sp. (19%) was found to be the most common species, while *Rapana venosa* (3%) was the rarest. Water quality parameters were evaluated considering the impact of the Sakarya River and the Küçükboğaz Stream on the region. It was observed that the distribution of benthic species was directly affected by breakwater and coastal erosion, which had a positive effect on the distribution of species such as *Mytilus galloprovincialis* and *Donax* sp. Although the Black Sea ecosystem is inefficient in terms of general species diversity, the region studied can be considered biologically productive. The study is also important because it provides horizontal observation of benthic organisms on the southwestern Black Sea coast and identifies risks of habitat loss along the coast.

Keywords: *Macrozoobenthos, Shannon-Weaver index, Margalef's richness index, physicochemical parameters, Karasu coast, Türkiye.*

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Introduction

Aquatic ecosystems are of great importance in terms of their biodiversity and ecological cycles. Benthic macroinvertebrates are one of the main components of these ecosystems and are considered important biological indicators of ecosystem health due to their sensitivity to the physicochemical properties of water (Bouchard, 2004). Benthic organisms are invertebrate species that generally live in sediments and feed on organic matter in the water column. They play a critical role in the biological balance of the ecosystem by directly responding to environmental factors such as salinity, temperature, dissolved oxygen, and substrate structure (Bat et al., 2011; 2024; Ürkmez et al., 2016).

As a closed sea, the Black Sea differs from other aquatic ecosystems in terms of ecological dynamics due to limited water exchange. In particular, low salinity, freshwater input, and limited water movement in the region directly affect the structure and distribution of benthic communities (Todorova et al., 2019). The Sakarya River, with a drainage basin of 56.504 km² and a total length of 824 km, is the second-largest Anatolian river discharging into the Black Sea, where it enters near the Karasu district. This region, situated within the boundaries of Sakarya Province, constitutes one of the most ecologically sensitive segments of Türkiye's Black Sea coastline and includes a 50 km shore shaped largely by river-borne sediments (Şeker et al., 2011). Together with the Küçükboğaz Stream along the western Black Sea coast, the Sakarya River exerts a significant influence on benthic ecosystems, as these freshwater inputs regulate species diversity and the spatial distribution of benthic communities. (Kılıç and Akpınar, 2022). In particular, suspended solids and nutrient loads carried by the Sakarya River affect the physical and chemical properties of benthic habitats by changing the sediment structure along the coast (Akbulut et al., 2022).

Studies of benthic macro fauna at the outlet of the Bosporus in the Black Sea revealed that species diversity has changed over time and the fluctuations in oxygen levels are a determining factor in species distribution (Mazlumyan and Boltachova, 2017). Furthermore, studies along the Turkish coast of the Black Sea show a strong relationship between water quality and benthic species diversity (Sergeeva and Ürkmez, 2017). Long-term analyses show a significant reduction in the diversity of benthic communities, especially in areas with intensive industrial and agricultural activities (Özcan et al., 2010; Turan et al., 2010; Gürlek et al., 2013; Ergüden et al., 2017; Revkov et al., 2018; Yücel et al., 2022).

Anthropogenic factors also cause significant changes in benthic ecosystems. Harbor structures, coastal protection projects, pollution, climate change, invasion of new alien species and breakwater constructions affect the habitat distribution of benthic communities by changing the ecosystem regime in the region (Kılıç and Akpınar, 2022). Physical interventions were found to increase the density of some benthic species through sediment deposition, while others may decline (Bat et al., 2011). In addition, studies conducted in the Thrace region have observed that agricultural and industrial activities cause changes in water quality, which in turn have adverse effects on benthic diversity (Çamur-Elipek et al., 2006).

The study aimed to determine the species diversity and distribution of benthic species on the Karasu coast between the Sakarya River and Küçükboğaz Stream. Sediment samples were collected from 15 different stations using the Ekman grab method, and the relationship between the distribution of benthic species and water quality parameters was analyzed. The physicochemical properties of water samples obtained from the stations on the Karasu coast revealed the effects of anthropogenic factors on the Karasu ecosystem.

Material and Methods

The study was conducted during the winter period (December 2024-February 2025) in the sampling area shown in Figure 1. Sampling was carried out at 15 stations, with their coordinates and depths listed in Table 1, located between the mouths of the Sakarya River and the Küçükboğaz Stream, extending from west to east. The collected macrozoobenthic species were identified using the diagnostic keys and methods indicated by Barnes et al. (2009). In addition, during the study period, the physicochemical parameters of the Karasu coastline were measured using a Water Quality Tester (HACH Lange). Sediment samples were collected using an Ekman Grab sampling device with a surface area of 1000 cm².

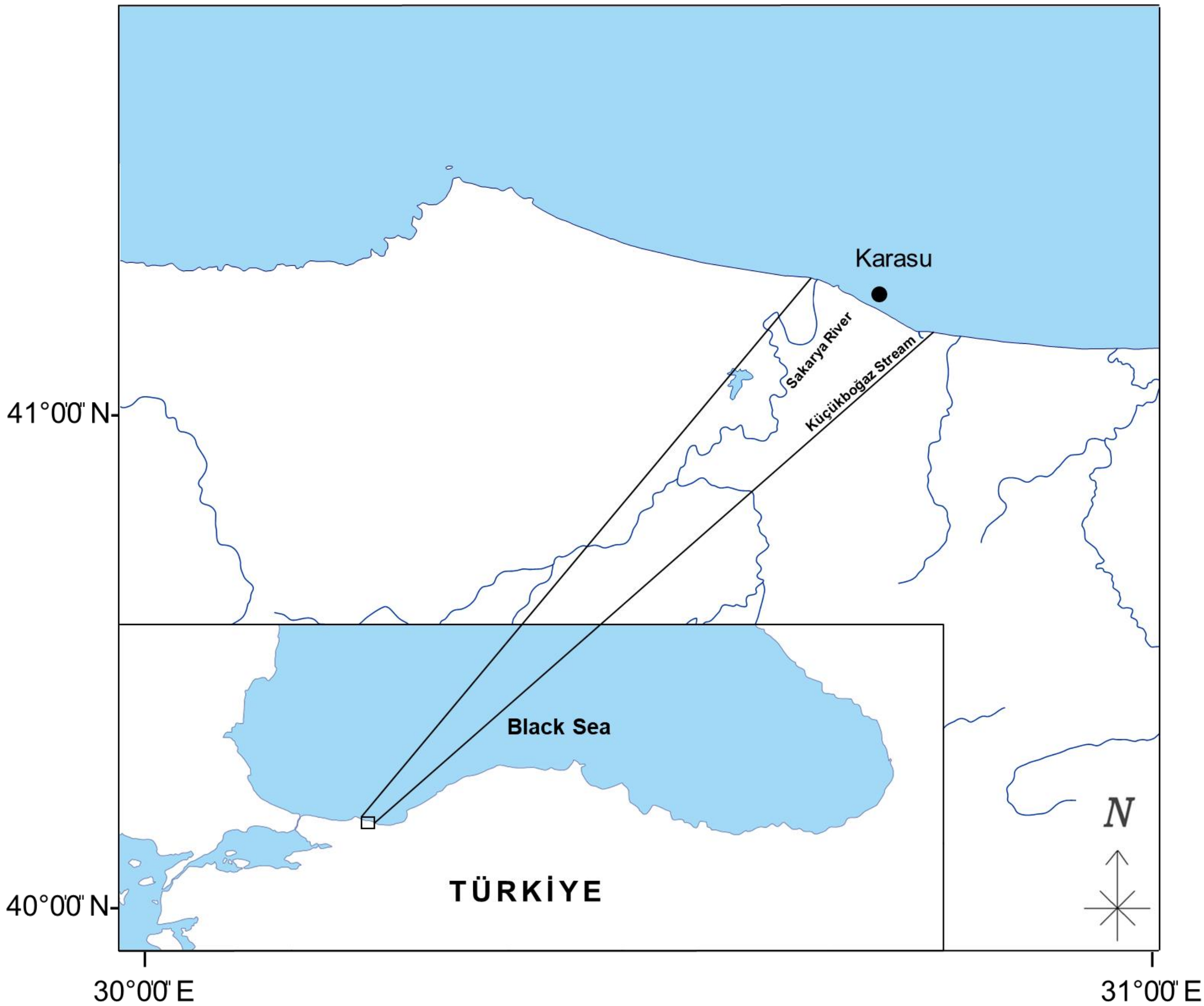

Figure 1. Map showing the sampling area along the Karasu coast, southwestern Black Sea.

Table 1. Geographical coordinates and depths of the sampling stations on the Karasu coast.

Stations	Latitude (°N)	Longitude (°E)	Depth (m)
1	41.12670	30.65488	7.9
2	41.12476	30.66119	8.3
3	41.12279	30.66791	4.2
4	41.11565	30.68299	7.5
5	41.11283	30.68861	3.7
6	41.11161	30.69293	3.2
7	41.11014	30.69892	5.6
8	41.10731	30.70640	5.2
9	41.10498	30.71200	3.6
10	41.10291	30.71768	4.4
11	41.10071	30.72358	5.1
12	41.09845	30.72923	4.5
13	41.09586	30.73539	6.2
14	41.09356	30.73926	4.5
15	41.09171	30.74345	3.8

Shannon-Weaver Diversity Index (*H'*) and Margalef's Species Richness (*d*) were used to provide complementary information about the biodiversity level and ecological integrity of the Karasu coastal ecosystem.

Shannon Index (Shannon and Weaver, 1949) was used to examine species distribution and diversity along the Karasu coast, estimating how the abundance of macrozoobenthic species in the area contributes to the overall diversity, based on the following formula:

$$H' = -\sum_{i=1}^{k} p_i \cdot \log_2(p_i)$$

where k is the total number of species, p_i is the proportion of individuals belonging to species i, and $\log_2(p_i)$ is the logarithm of p_i to the base 2.

Margalef Index was used to assess the species richness of the Karasu coastal ecosystem by adjusting the number of species in relation to the total number of individuals present, and was calculated using the following formula (Margalef, 1958):

$$d = \frac{S - 1}{\log_2(n)}$$

where S is the total number of species observed in the community, n is the total number of individuals, and $\log_2(n)$ is the logarithm of n to the base 2.

Statistical analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA).

Result and Discussion

A total of 15 sampling stations were established along the transect extending from the western side of the Sakarya River mouth to the eastern side of the Küçükboğaz Stream mouth, selected to represent the structural and ecological characteristics of macrozoobenthic communities. Their spatial distribution was examined over a three-month period encompassing the winter season. Additionally, surface water samples were collected monthly during this period for physicochemical measurements, followed by a thorough investigation.

The findings of the study revealed that the distribution and abundance of macrozoobenthic species along the Karasu coastal ecosystem may vary depending on depth. The distribution of macrozoobenthic species between stations and depths in winter was presented in Table 2 with Shannon and Margalef index values for each station, thus showing the variation in species richness and abundance.

Table 2. Distribution of macrozoobenthic organisms by station and depth, with Shannon and Margalef index values during the winter season in Karasu coastal ecosystem.

Species	**Stations**														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Depth (m)														
	7.9	8.3	4.2	7.5	3.7	3.2	5.6	5.2	3.6	4.4	5.1	4.5	6.2	4.5	3.8
Anadara kagoshimensis	1	5	1	1	-	1	-	4	2	1	1	1	2	-	3
Chamalea gallina	2	-	-	3	2	-	2	3	5	4	-	3	-	2	1
Donax sp.	2	4	6	-	1	-	5	1	3	1	2	1	7	1	2
Venus sp.	1	2	-	3	1	3	-	2	-	3	3	2	3	2	4
Venus foveolata	-	3	3	1	-	1	2	2	1	-	-	3	-	1	-
Tritia neritea	-	1	3	-	3	1	-	-	1	1	-	3	2	1	2
Rapana venosa	1	-	-	-	1	-	-	1	-	2	-	-	-	1	-
Mytilus galloprovincialis	1	5	6	2	3	-	2	2	1	4	-	2	3	-	2
Total number of individuals	8	20	19	10	11	6	11	15	13	16	6	15	17	8	14
Shannon Index (*H'*)	5.66	5.36	4.33	4.50	5.33	3.15	2.82	5.16	5.59	7.80	2.65	5.02	4.16	4.78	6.49
Margalef's Index (*d*)	2.40	1.67	1.36	1.74	2.08	1.67	1.25	2.22	1.95	2.16	1.12	2.21	1.41	2.41	1.89

During the study period, the highest abundance was observed in Station 2 (20 individuals) and the lowest in Station 6 (6 individuals). Shannon index (*H*') ranged from 2.65 (Station 11) to 7.80 (Station 10) between stations. On the other hand, the minimum Margalef index (*d*) was observed at Station 11 (1.12), while the maximum was at Station 14 (2.41) and Station 1 (2.40).

In total, eight species were identified across all sampling stations along the Karasu coast; the class Bivalvia was the dominant group with 6 species (*Anadara kagoshimensis*, *Chamelea gallina*, *Donax* sp., *Venus* sp., *Venus foveolata* and *Mytilus galloprovincialis*), while the class Gastropoda comprised the remaining 2 species (*Tritia neritea* and *Rapana venosa*). At most stations, *C. gallina*, *Donax* sp., and *M. galloprovincialis* were the dominant species, whereas *R. venosa* and *V. foveolata* exhibited restricted distribution and low abundance.

The percentage distribution of species at the stations was demonstrated in Figure 2. *Donax* sp. (19%) and *M. galloprovincialis* (18%), observed in approximately all stations, were the most dominant benthic species, while *R. venosa* (3%) had the lowest distribution. The results suggest that the distribution of macrozoobenthic species may depend on specific habitat characteristics or their ability to resist competitive pressure within the benthic community.

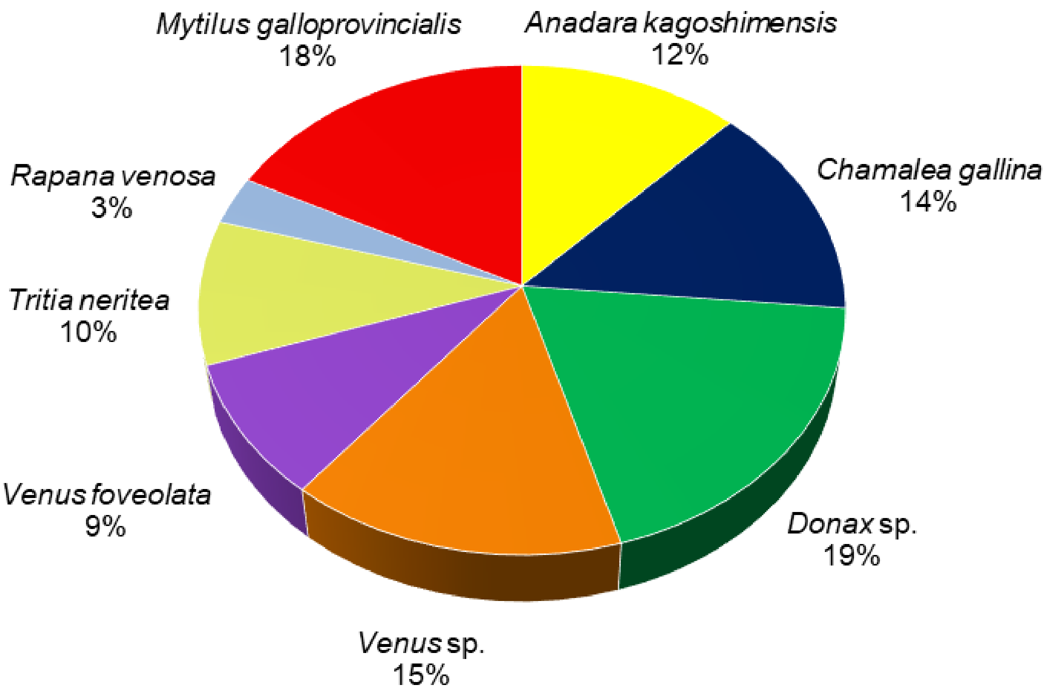

Figure 2. Relative abundance of macrozoobenthic organisms observed in Karasu coastal ecosystem.

Figure 2 showed that in the Karasu coastal ecosystem, macrozoobenthic organisms are mainly dominated by species belonging to the class Bivalvia class (*Donax* sp., *M. galloprovincialis*, *Venus* spp., *Anadara kagoshimensis*, and *Chamelea gallina*). As suspension-feeding bivalves, especially *Donax* sp. occupy the swash zone of exposed sandy beaches, where they frequently occur at high densities and maintain a vertical orientation within the sediment across tropical and temperate coasts worldwide. When displaced by wave action, these small clams exhibit rapid reborrowing behavior, a trait that enhances their persistence in dynamic environments. Owing to their pronounced sensitivity to environmental fluctuations, *Donax* sp. are widely recognized as reliable bioindicators of beach ecosystem integrity (Donoghue, 1999).

The findings of this study have also indicated that the sandy bottom of the Karasu coastline does not provide stable and suitable conditions for the species of class Gastropoda observed there (*T. neritea* and *R. venosa*). Characterized by high reproductive and growth rates and tolerance to a wide range of salinity, temperature, pollution, and hypoxic conditions, *R. venosa* possesses significant ecological resilience. As a highly predatory gastropod, it has contributed to detrimental changes in the structures of regional benthic communities, playing a role in the decline of native bivalve populations in the Black Sea (Moncheva et al., 2011). Despite this, it was the least distributed species observed in the study area. This paradoxical situation could be attributed to *R. venosa*'s inability to adequately resist pressure from nutrient competition within the benthic community or to limitations related to its specific environmental requirements. Furthermore, supporting evidence from other studies along the Turkish Black Sea coast indicates that human-induced pressures, changing nutrient regimes, and hydrodynamic variability further trigger differentiation in benthic community composition (Sergeeva and Ürkmez, 2017; Revkov et al., 2018).

Differences observed in the Shannon-Weaver Diversity Index and Margalef's Species Richness Index among sampling stations along Karasu coast suggest that the macrozoobenthic community structure is spatially heterogeneous. Stations with high *H'* (e.g., Stations 10 and 15) point to communities where species are more evenly distributed in terms of abundance, while stations with low *H'* (e.g., Stations 7 and 11) reflect structures where a few species are dominant (Wickham et al., 2000; Magurran, 2013). Station 11 recorded the lowest Shannon ($H' = 2.65$) and Margalef ($d = 1.12$) values, likely due to low species richness and an uneven spread of abundance. Low Margalef values are usually linked to habitats where only a few species are present, and environmental conditions support the existence of certain species only (Roy et al., 2014; Nagendra and Reddy, 2019). Conversely, in some stations, Margalef values were relatively high while Shannon values did not increase to the same extent. This is a potential indication that the distribution of species richness and abundance does not always change in parallel. However, Stations 10 and 15 had high Shannon values, indicating a more balanced distribution of species and suggesting that these stations may provide more favorable habitat conditions for benthic organisms. Such a pattern is common in communities where species numbers are high, but individuals are concentrated in a few dominant species, a situation often observed in benthic ecosystems (Gray and Elliott, 2009; Tett et al., 2013; Chatzinikolaou et al., 2018).

Spatial differences in macrozoobenthic communities are usually related to factors such as sediment type, depth, hydrodynamic conditions, and local environmental pressures. Previous studies have shown that benthic organisms are highly sensitive to these variables, and even small-scale habitat differences can lead to clear changes in community structure (Ponti et al., 2008; Sangiorgio, 2011; Mazlumyan, 2019; Lazar et al., 2021). Therefore, evaluating Shannon and Margalef indices together allows not only the number of species but also their relative abundances to be considered, providing a more comprehensive and reliable interpretation of macrozoobenthic ecosystem structure.

Although the Black Sea is relatively limited in benthic species diversity compared to other marine ecosystems, it is distinguished globally for its high biological productivity. This productivity stems from its semi-enclosed nature and the accumulation of terrestrial organic matter transported by rivers (Alkan et al., 2022). However, Karasu coastline has undergone pronounced alterations as a result of coastal erosion, particularly following the construction of Karasu Port. Landward retreat of the shoreline and modifications in the seabed structure have led to substantial transformations in coastal morphology. Breakwaters, established to mitigate erosion and rising sea levels, exert direct influence on habitat dynamics by providing shelter and attachment surfaces for species such as *M.*

galloprovincialis (Kılıç and Akpınar, 2022). Moreover, these structures promote the formation of sand accumulations in low-current zones, thereby enhancing the abundance of psammophilic species along the shore.

A detailed physicochemical evaluation was performed on surface water samples collected 3 times in total, once a month from each station. The findings were summarized in Table 3 and contributed to the development of a conceptual framework in relation to the spatial distribution of benthic organisms in the study area.

Table 3. Mean (± standard deviation) values of physicochemical parameters measured at each station along the Karasu coastline during a three-month sampling period.

Stations	pH	Conductivity (mS/cm)	Salinity (psu)	Temperature (°C)	Dissolved O_2 (mg/L)	O_2 Saturation (%)
1	8.3±0.05	21.4±0.18	18.5±0.12	11.3±0.2	9.51±0.04	95.6±0.4
2	8.2±0.04	21.0±0.22	18.1±0.10	11.2±0.1	9.54±0.03	95.7±0.3
3	8.3±0.03	21.2±0.15	18.1±0.08	11.1±0.2	9.53±0.05	95.9±0.5
4	8.3±0.04	20.8±0.20	18.5±0.09	11.1±0.2	9.54±0.04	95.8±0.4
5	8.1±0.05	21.1±0.17	18.1±0.11	11.2±0.1	9.51±0.05	95.6±0.5
6	8.0±0.03	21.3±0.19	18.1±0.10	11.3±0.2	9.53±0.04	95.3±0.4
7	8.2±0.06	21.3±0.16	18.3±0.09	11.3±0.2	9.54±0.03	95.9±0.3
8	8.1±0.02	21.1±0.18	18.2±0.10	11.2±0.1	9.52±0.04	95.6±0.4
9	8.1±0.04	20.7±0.21	18.5±0.12	11.2±0.1	9.54±0.05	95.7±0.5
10	8.4±0.03	20.8±0.19	18.4±0.11	11.4±0.2	9.55±0.04	95.9±0.4
11	8.3±0.04	20.9±0.20	18.2±0.10	11.3±0.1	9.53±0.03	95.3±0.3
12	8.4±0.05	21.4±0.17	18.4±0.09	11.6±0.2	9.51±0.05	95.5±0.5
13	8.3±0.05	21.3±0.18	18.3±0.10	11.6±0.2	9.53±0.04	95.7±0.4
14	8.3±0.03	20.8±0.16	18.2±0.11	11.4±0.2	9.54±0.03	95.9±0.3
15	8.4±0.01	20.9±0.15	18.2±0.08	11.3±0.1	9.52±0.04	95.9±0.4

The physicochemical parameters measured at the sampling stations exhibited spatial variability across the study area. The shallowest station was recorded at 3.2 m in Station 6, whereas the deepest station was identified at 8.3 m in Station 2. Mean water temperature ranged between 10.5-10.8°C, with the lowest values observed in Stations 3, 4, and 11, and the highest values in Stations 10, 12, and 13. Mean salinity values varied between 18.1-18.5 psu, the lowest salinity was measured in Stations 2, 3, 5, and 6, while the highest values were recorded in Stations 1, 4, and 9. pH values ranged from 8.0 to 8.4 on average, with the lowest value in Station 6 and the highest in Stations 10, 12, and 15. Average conductivity ranged from 20.7 to 21.4 mS/cm, with the lowest reading in Station 9 and the highest in Stations 1 and 12. Dissolved O2 averaged between 9.51 and 9.55 mg/L, with the lowest values in Stations 1, 5, and 12, and the highest in Station 10. O2 saturation varied between 95.3%-95.9% on average, with the lowest values in Stations 6 and 11, and the highest in Stations 3, 7, 10, 14, and 15.

These findings provide important insights into the physicochemical characteristics of the study area and highlight pronounced spatial heterogeneity, largely influenced by freshwater inputs from the Sakarya River and the Küçükboğaz Stream. The salinity values, consistent with the estuarine nature of the Black Sea, indicate that benthic species composition is shaped by these hydrographic conditions (Bat et al., 2011; Mousing et al., 2013). The relatively narrow range of pH values suggests that the region provides a well-buffered environment for benthic organisms. Furthermore, dissolved O2 concentrations and saturation levels indicate that oxygen availability is not a limiting factor in the area, thereby supporting relatively high macrozoobenthic diversity.

In conclusion, this study provides a comprehensive assessment of the ecological structure of the region by revealing the macrozoobenthic diversity and physicochemical parameters along the Karasu coast. The study also provides an important reference point for long-term monitoring of benthic communities in the southwestern Black Sea. Human-induced coastal engineering projects, freshwater inputs, and changes in coastal dynamics directly affect the structure of benthic communities, and the impacts of these factors on ecosystem health should be continuously monitored. Future studies would benefit from examining the structure of benthic communities in the Black Sea, taking into account freshwater inputs, the nature of coastal hydrodynamics, seasonal effects, and changes in sediment composition.

Conflict of Interest

The authors declare that for this article they have no actual, potential or perceived conflict of interest.

Author Contributions

The authors performed all the experiments and drafted the main manuscript text. All authors reviewed and approved the final version of the manuscript.

Ethical Approval Statements

No ethics committee permissions are required for this study.

Data Availability

The data used in the present study are available upon request from the corresponding author.

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