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RESEARCH

# Molluscs Associated with Phanerogams in the Sea of Marmara

Banu Bitlis[1] · Bilal Öztürk[2] · Alper Doğan[2] · Neslihan Türkçü[2]

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**Abstract**

The present study was conducted to identify the molluscan species associated with the *Posidonia oceanica* and *Zostera marina* meadows in the Marmara Sea. The investigated benthic material was taken from seven stations at depths up to 7 m by utilizing a quadrate sampler (20 × 20 cm) and was randomly collected by snorkeling and scuba diving from three stations in 2012. Faunistic examination revealed a total of 73 mollusc species pertaining to the classes of Polyplacophora, Gastropoda, and Bivalvia. Among the identified species *Haliotis tuberculata* Linnaeus, 1758, *Obtusella macilenta* (Monterosato, 1880), and *Thylaeodus rugulosus* (Monterosato, 1878) are new records from the region. The families Rissoidae (13 species), Mytilidae (7 species), and Veneridae (6 species) were found in the greatest number of species, and the most abundant mollusc species included *Bittium reticulatum* (da Costa, 1778) (63.70% of the total number of individuals), and *Rissoa ventricosa* Desmarest, 1814 (18.40%). According to Pearson's correlation analysis, the number of species and the number of specimens exhibited positive correlations with phosphorus ($r = 0.86$ and $r = 0.72$, $p < 0.05$). CCA analysis revealed that Chl-a was correlated with the first axis, whereas salinity, Chl-a, dissolved oxygen, and phosphorus were connected with the second axis.

**Keywords** Mollusca · *P. oceanica* · *Z. marina* · Ecology

## Introduction

The Sea of Marmara, covering an approximate area on the surface of 11.500 km$^2$, 70 km width and 240 km length, has a few narrow and long straits namely as the Dardanelles and Bosphorus Straits in the European-Mediterranean region (Özsoy 2016). Dardanelles (Çanakkale Strait) provides a link between the Sea of Marmara and Aegean Sea, likewise the Bosphorus Strait connects the Sea of Marmara to the Black Sea. The Turkish Straits System, a system of channels that links the Mediterranean and Black Seas, is significant for exchange of water and materials. According to Presidential Decision dated 04.11.2021, numbered 4758 and published in the Official newspaper, the Sea of Marmara and its Islands were declared as a Special Environmental Protection Area.

Since the eighteenth century, the Sea of Marmara has been a focal point of interest for many researchers. The initial study of molluscan fauna, including benthic invertebrates on Turkish coasts, was carried out by Forsskâl (1775), who collected marine algae from the coasts of Bosphorus, Dardanelles, and Tekirdağ in the Sea of Marmara and the Aegean Sea. This was followed by the studies of Colombo (1885) and Ostroumoff (1894) on the macrozoobenthic species of Dardanelles and Bosphorus Strait, respectively. Ostroumoff briefly reported molluscan species among many invertebrate species from the Marmara Sea two years later (Ostroumoff 1896).

Although there have been many researchs on benthic invertebrate species in this area, a few studies regarding only molluscan fauna have been performed in subsequent centuries. Kowalevsky (1901) recorded two caudofoveats from the region. It was followed by significant investigations in which many mollusc species were reported inhabiting different habitats (Pallary 1917; Oberling 1969–1971; Bitlis et al. 2010; Kabasakal et al. 2011). In recent years, Doğan et al. (2016) listed 28 molluscan species found in the bathyal zone of the Marmara Sea. Afterwards, 52 opisthobranch species belonging to 32 families were identified by Artüz et al. (2018). In 2019, 30 species encompassing the classes Polyplacophora, Gastropoda, and Bivalvia in association with *Cystoseira barbata* were reported from the Marmara Sea

✉ Banu Bitlis
banu.bitlis@deu.edu.tr; banubitlis@yahoo.com

[1] Institute of Marine Sciences and Technology, Dokuz Eylul University, 35430 Balçova, İzmir, Türkiye

[2] Department of Hydrobiology, Faculty of Fisheries, Ege University, 35100 Bornova, İzmir, Türkiye

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(Bitlis 2019). Finally, Özalp et al. (2022) investigated zoobenthic species from hard coral habitats on the Dardanelles coasts.

Seagrass meadows are an essential marine coastal ecosystem for the production of oxygen using photosynthesis, capturing the particles and sediments for regulating the sea floor by their long leaves. They reduce coastal erosion and supply a significant nursery area for many marine species by providing substrates for many epibiont species (Cirik and Akçalı 2013).

Only four of the marine phanerogams known from the Turkish coasts [*Cymodocea nodosa* (Ucria) Ascherson, *Posidonia oceanica* (Linnaeus) Delile, *Zostera marina* Linnaeus and *Nanozostera noltei* (Hornemann) Tomlinson & Posluszny] are distributed along the Sea of Marmara (Taşkın et al. 2008). It was reported by Cirik and Akçalı (2013) that the coastline of the seagrasses meadows stretched out 5–6 km and was sparse in the Marmara Sea. According to the International Union for Conservation of Nature's Red list of threatened species, *P. oceanica* and *Z. marina*, which are the phanerogams researched in this study, have been assessed to the least of concern category since the year 2013. It has been announced that the current population trend is decreasing in the Mediterranean Sea (Buia and Pergent-Martini 2015; Pergent et al. 2016). *Posidonia oceanica*, a Mediterranean endemic species, is also called the lungs of the Mediterranean Sea. It is a perennial species that can live thousands of years with vegetative proliferation (Cirik and Akçalı 2013). *Zostera marina*, which is the other phanerogam investigated in the present study, usually creates dense meadows in muddy sand or sandy bottoms or substrates in lagoons, protected bays, and the mouths of rivers. *Zostera marina* is an euryoecious species with distribution encompassing the entire Mediterranean Sea and Turkish coastline (Çınar et al. 1998). It also has an important distribution elsewhere in the Northern Hemisphere, in the Atlantic, and Pacific Oceans (Green and Short 2003).

Studies on marine invertebrate and molluscan assemblages of phanerogam meadows have been concentrated in the Western and Central Mediterranean on a global scale (Templado 1984; Bonfitto et al.1997; Beqiraj et al. 2008; Urra et al. 2011; Belgacem et al. 2013). Moreover, in some investigations, the climatic and geographical fluctuations of mollusc communities or marine benthic invertebrates inhabiting the leaves and rhizomes of *P. oceanica* and *Z. marina* were thoroughly examined in the western Mediterranean Sea (Russo et al. 1991; Vetere et al. 2006; Belgacem et al. 2011; Urra et al. 2013; Bedini et al. 2015). However, a few studies are available regarding the molluscan and benthic fauna associated with marine phanerogams in the Turkish coasts and eastern Mediterranean Sea (Çınar et al. 1998; Doğan et al. 2013; Holzknecht and Albano 2022). Çınar et al. (1998) studied zoobenthic organisms from *Z. marina* meadows in Gülbahçe Bay on the Aegean coast of Türkiye and reported only 7 Bivalvia species belonging to the phylum Mollusca. Benthic studies associated with *P. oceanica* along the Turkish coasts were compiled within the frame of the list given by Doğan et al. (2013). Recently, the molluscan assemblage of *P. oceanica* was studied from the Crete coasts in the eastern Mediterranean by Holzknecht and Albano (2022).

Although mollusc species in the Sea of Marmara have been the subject of some studies (Kaneva-Abadjieva 1959; Müller 1985; Albayrak et al. 2006; Ritt et al. 2012), only a few papers have focused on the molluscs associated with *P. oceanica* and *Z. marina* in this area (Ostroumoff 1896; Aslan-Cihangir and Ovalis 2013; Öztürk et al. 2014; Artüz et al. 2018).

The objective of this study was to provide data on molluscan diversity in association with *P. oceanica* and *Z. marina* in the Sea of Marmara, with a particular focus on abundance patterns, species composition, and dominance relationships. Moreover, the study aimed to assess the connections between environmental factors and mollusc assemblages, as well as various community structures.

## Material and Methods

The subjected material was obtained within the framework of a TUBITAK CAYDAG project (111Y268) held along the Sea of Marmara in 2012. Seven stations were selected to investigate the mollusc fauna of the phanerogam meadows in the Marmara Sea (Fig. 1). Benthic samples were collected at depths up to 7 m using a quadrate sampler (20 × 20 cm) and randomly by snorkelling and Scuba diving (Table 1). Three replicates were taken at each station using a quadrate, which is a frame. Random samplings were performed only at three stations (St. 1, St. 3, St. 8) on *P. oceanica*. The materials were scraping with a spatula and put into the bag in the bottom. Then washed with water on a 0.5 mm mesh and stored in jars with 4% seawater formalin solution in the field. The benthic materials in jars were first washed with water on a 0.5 mm mesh and sorted into high taxonomic groups under a stereomicroscope, and preserved in 70% alcohol in the laboratory. The mollusc specimens were then identified, updated, counted, and their total wet weight was estimated using a scale with a sensitivity of 0.0001 g. The classification of the identified mollusc species was based on the World Register of Marine Species (WoRMS Editorial Board, 2023). The specimens were deposited at the Museum of the Faculty of Fisheries at Ege University (ESFM) in İzmir, Türkiye.

The temperature, salinity, and dissolved oxygen concentrations were measured in the field using a SCT meter (YSI 100 model) and an oxygen meter (YSI 55 model). Water

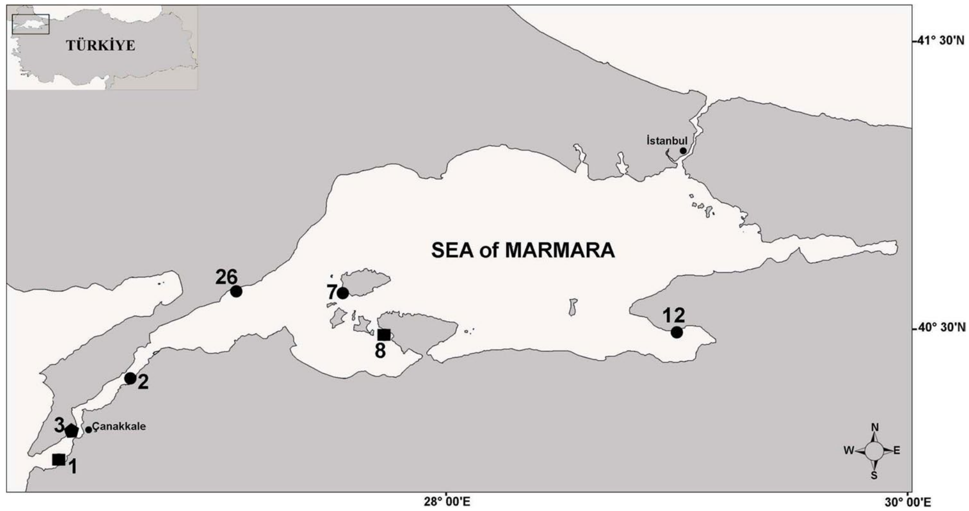


**Fig. 1** Map of the study area and location of the sampling sites

samples collected for chemical analysis were placed in jars, frozen, and transferred to the laboratory. Then, pH, nutrients (nitrite, nitrate, ammonnium, phosphate phosphorus and silicate) and chlorophyll *a* content were analyzed using a pH meter (Orion brand) and a spectrophotometer method (Parsons et al. 1984).

### Statistical Analyses

For each sample, community structures, including the number of species, number of individuals, their relative abundance, and the total biomass (wet weight) of the molluscs were calculated. The Soyer's (1970) frequency index (F), Bellan Santini's (1969) dominance index (D), Pielou's (1975) evenness (J'), and Shannon and Weaver (1949) diversity ($\log_2$ base) (H') indices were estimated for each station. The community parameters were mapped and processed using SURFER software programme. Pearson's correlation analysis was employed to examine connections between environmental factors and community descriptors, such as the number of species, number of specimens, total biomass (wet weight), evenness, and diversity indices. The relationship between environmental parameters and mollusc assemblages was analyzed by Canonical correspondence analysis (CCA). Prior to cluster analysis, raw data were transformed using the formula $yji = \log (xji + 1)$. Monte Carlo permutations were employed to determine the importance of the ordination axes. The analyses were conducted using the software packages STATISTICA, SURFER, and PRIMER 5.

## Results

A total of 3888 individuals and 73 molluscan species from 33 families and 3 classes (Polyplacophora, Gastropoda, and Bivalvia) were identified in the Sea of Marmara, as a result of faunistic analysis (Supplementary Table). The class Gastropoda was represented by 17 families and 42 species, subsequently Bivalvia (14 families and 29 species) and Polyplacophora (2 families and 2 species). The families Rissoidae (13 species), Mytilidae (7 species) and Veneridae (6 species) exhibited the highest species diversity among the 33 families detected in this study.

**Table 1** Coordinates, sampling dates, depth range, biotopes, sampling gear, and localities of the sampling sites

| Stations | Coordinates | Date | Depth range (m) | Biotopes | Sampling gears | Localities |
|---|---|---|---|---|---|---|
| 1 | 40.027500°N- 26.332500°E | 25.09.2012 | 0–10 | *P. oceanica* | Quadrat Random | Dardanelles, Güzelyalı |
| 2 | 40.291389°N- 26.615556°E | 26.09.2012 | 0–10 | *Z. marina* | Quadrat | Dardanelles, Suluca |
| 3 | 40.133333°N-26.356944°E | 06.10.2012 | 0–4 | *Z. marina*, *P. oceanica* | Quadrat Random | Dardanelles, Havuzlar |
| 7 | 40.593611°N-27.546667°E | 28.09.2012 | 0–10 | *Z. marina* | Quadrat | Island of Marmara |
| 8 | 40.467500°N- 27.709722°E | 27.09.2012 | 0–7 | *P. oceanica* | Random | Erdek |
| 12 | 40.457778°N-28.976944°E | 30.09.2012 | 0–10 | *Z. marina* | Quadrat | Kapaklı |
| 26 | 40.608333°N- 27.096944°E | 05.10.2012 | 0–3 | *Z. marina* | Quadrat | Şarköy |

**Table 2** Number of species (S), number of specimens (N), wet weight (g.m$^{-2}$) (B), and frequent and dominant species in *P. oceanica* and *Z. marina*

| Phanerogams | S | N | B | Frequent species % | Dominant species % |
|---|---|---|---|---|---|
| *Posidonia oceanica* | 55 | 353 | 12.15 | *S. adansonii* 71% *B. reticulatum* 71% *A. discors* 71% *A. mamillata* 71% *R. membranacea* 57% | *B. reticulatum* 57% *B. eulimoides* 12% |
| *Zostera marina* | 35 | 3103 | 52.48 | *B. reticulatum* 80% *R. ventricosa* 80% *T. reticulata* 67% S. *adansonii* 53% | *B. reticulatum* 66% *R. ventricosa* 23% |

Of the identified species, the most abundant were *Bittium reticulatum* (da Costa, 1778), accounting for 63.70% of the total number of specimens, and *Rissoa ventricosa* Desmarest, 1814 (18.40%). Only 5 species [*Steromphala adansonii* (1.36%), *Brachystomia eulimoides* (1.05%), *Polititapes rhomboides* (1.02%), *Macomangulus tenuis* (1.02%) and *Loripinus fragilis* (1.00%)] had dominance scores higher than 1%, while the remaining species had scores lower than 1%.

According to frequency index values, 4 species [*B. reticulatum* (77%), *R. ventricosa* (68%), *Steromphala adansonii* (59%) and *Rissoa membranacea* (50%)] were represented in more than 50% of the samples as constant species on the phanerogam meadows of the Sea of Marmara. However, 4 species [*Tritia reticulata* (45%), *Chamelea gallina* (32%), *Alvania discors* (27%) and *Mytilus galloprovincialis* (27%)] were represented in less than 49% of the samples, while 65 species appeared in less than 25% of the samples and were rarely collected in the study area.

Considering the two phanerogams separately, 55 species were sampled from *P. oceanica* and 35 species from *Z. marina* in the quantitative sampling sites by a quadrate sampler (Table 2). However, the number of species in *P. oceanica* was higher than that in *Z. marina*, and the number of specimens and biomass in *Z. marina* (3103, 52.48 g.m$^{-2}$) were higher than those in *P. oceanica* (353, 12.15 g.m$^{-2}$). As for the frequency index values, *B. reticulatum* and *S. adansonii* were the most frequent species in both phanerogams. The most abundant species were *B. reticulatum* (57%) and *B. eulimoides* (12%) in *P. oceanica*, and *B. reticulatum* (66%) and *R. ventricosa* (23%) in *Z. marina* (Table 2).

Among the molluscs identified in the present study, *H. tuberculata* Linnaeus 1758, *O. macilenta* (Monterosato 1880), and *T. rugulosus* (Monterosato 1878) are new records from the Sea of Marmara (Fig. 2). *H. tuberculata* is known along the Turkish Levantine and Aegean coasts (Aartsen and Kinzelbach 1990; Buzzurro and Greppi 1996). The other species, *O. macilenta* was first recorded from the Turkish Aegean coasts by Demir (2003) and was encountered at the Levantine coasts of Türkiye (Bitlis-Bakır and Öztürk 2016), and *T. rugulosus* was previously reported from the Levantine and Aegean coasts of Türkiye by Demir (2003).

***Class: Gastropoda*** Subclass: Vetigastropoda Order: Lepetellida Family: Haliotidae Genus: Haliotis Haliotis tuberculata **Linnaeus** 1758 **(Fig.** 2**C)**

*Haliotis tuberculata* Linnaeus 1758: 780 (original description).
*Haliotis adriatica* Nardo, 1847

**Material examined** St. 1, 1 sp. (ESFM - GAS/2012-18)

***Remarks*** The shell is flat, and having 3–4 teleoconch whorls, axial ribs, and growth lines on its surface, which intersect between them. There are 5–7 small holes in a single row on the columellar edge of the aperture. The inner part of the shell is coated with a pearl layer. The color of the shell varies depending on its substratum.

**Distribution** Mediterranean Sea (Buzzurro and Greppi 1996), Turkish coasts: Levantine Sea (Buzzurro and Greppi 1996: 4), Aegean Sea (Aartsen and Kinzelbach 1990: 104; Demir 2003: 103), Marmara Sea (this study).

***Class: Gastropoda Subclass: Caonogastropoda Order: Littorinimorpha Family: Rissoidae Genus: Obtusella Obtusella macilenta* (Monterosato** 1880**) (Fig.** 2**A, B)**

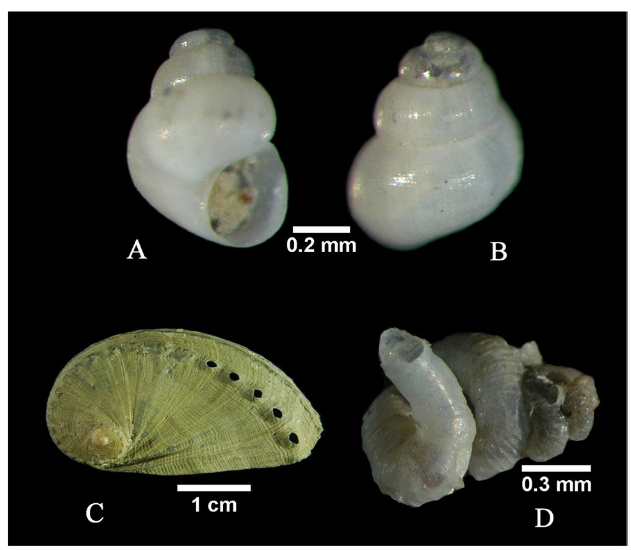


**Fig. 2** Mollusc species newly additions to mollusc fauna of the Marmara Sea (**A**, **B** *O. macilenta* H = 0.75 mm, **C** *H. tuberculata* H = 36.8 mm, **D** *T. rugulosus* Ø = 1.0 mm)

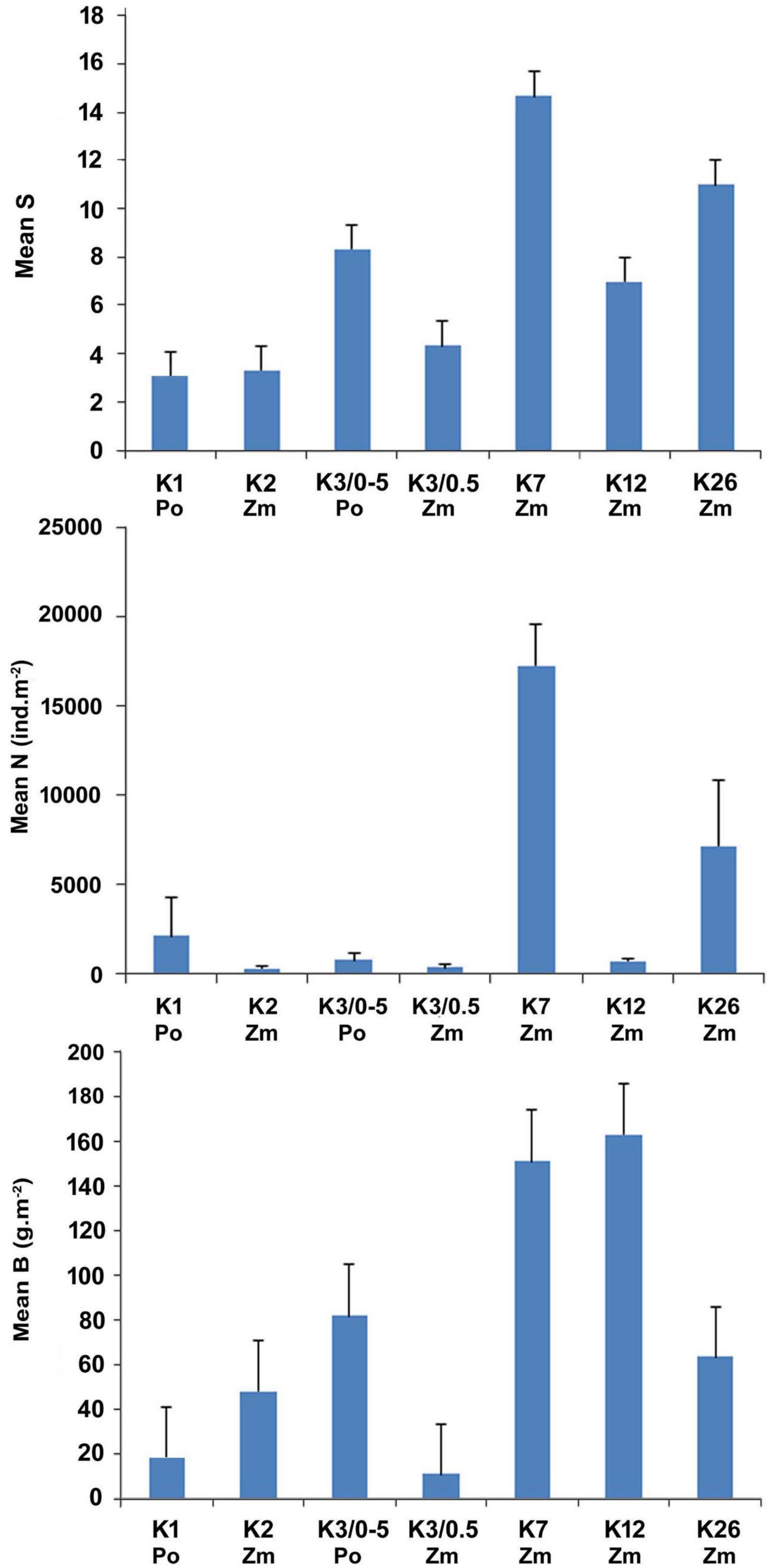


**Fig. 3** Mean number of species, specimens, and wet weight at each station, with "±" standard errors

*Setia macilenta* Monterosato 1880: 69 (original description).

*Cingula macilenta*; Aartsen and Verduin 1982: 128, Fig. 1

**Material examined** St. 26, 1 sp. (ESFM - GAS/2012-20)

***Remarks*** The shell is conical shape, with 4 convex teleoconch whorls and a round apex. The umbilical chink is narrow and evident. The aperture is rounded, and labrum smooth. The shell is shiny, and whitish or brownish. It is distinguishable from the *Obtusella intersecta* (S. Wood, 1857) by the lack of spiral sculpture on the shell surface.

**Distribution** Eastern Atlantic Ocean and Mediterranean Sea (Aartsen and Verduin 1982; Bouchet and Warén 1993). Turkish coasts: the Levantine Sea (Bitlis-Bakır and Öztürk 2016), the Aegean Sea (Demir 2003), and the Sea of Marmara (the present study).

***Class: Gastropoda Subclass: Caenogastropoda Order: Littorinimorpha Family: Vermetidae Genus: Thylaeodus Thylaeodus rugulosus*** **(Monterosato 1878) (Fig. 2D)**

*Vermetus rugulosus* Monterosato 1878: 89 (original description).

**Material examined** St. 1, 1 sp. (ESFM - GAS/2012-19)

***Remarks*** The shell is thin and in the form of a cylindrical tube with prominent regular ribs. No spiral sculpture on the surface of the shell with a round aperture. The color of the shell is white or yellowish beige.

**Distribution** Mediterranean Sea (Gianuzzi-Savelli et al. 1997), and Atlantic Ocean (Bieler 1995). Turkish coasts: the Levantine Sea (Demir 2003: 109; Çevik and Sarıhan 2004: 95), the Aegean Sea (Demir 2003), and the Sea of Marmara (the current study).

The mean number of species and individuals, mean wet weight, values of evenness and diversity indices with ± standard errors are illustrated in Figs. 3 and 4 at the stations. The highest mean number of species and specimens were found at station 7 (14.7 species and 17,250 ind.m−2), followed by station 26 (11 species and 7183 ind.m−2). The highest mean wet weight value, as well as the values of evenness and diversity indices were calculated at station 12 (163 g.m−2, H' = 2.44, J' = 087) (Figs. 3 and 4).

The average values of community parameters in the samples, including the number of species, number of specimens,

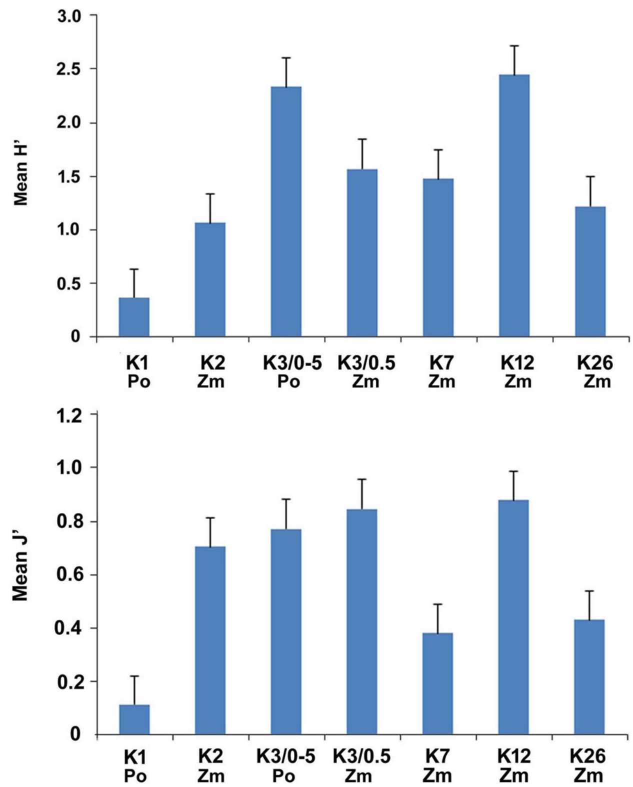


**Fig. 4** Mean evenness and diversity indices at each station, with "±" standard errors

total mean wet weight, evenness, and diversity indices at each station are depicted in Figs. 5 and 6. The lowest mean number of species (3.3 species) was found at stations 1 and 2, while stations 2 and station 3/0.5 had the lowest mean number of specimens (308 ind.m$^{-2}$, 367 ind.m$^{-2}$). The greatest mean wet weight (i.e. biomass) was recorded at station 12, followed by station 7 (151 g.m$^{-2}$) and station 3/0–5 (82 g.m$^{-2}$). The lowest mean values of diversity and evenness indices were found at station 1 (H' = 0.4, J' = 0.1), while the greatest mean values were recorded at station 12 (Figs. 5 and 6).

Pearson's correlation analysis revealed a significant increase in the number of species in the associated fauna with rising phosphorus levels ($r = 0.86$, $p < 0.05$), and the number of specimens exhibited a positive correlation with silicate ($r = 0.75$, $p < 0.05$) and phosphorus ($r = 0.72$, $p < 0.05$) (Table 3).

Based on the CCA analysis, environmental variables influencing the distribution of molluscs were shown (Table 4; Fig. 7). Strong correlations between the species and environmental factors were detected along the first two canonical axes (r = 0.984 and 0.965 for axes 1, 2). The Monte Carlo test showed statistical significance for all canonical axes

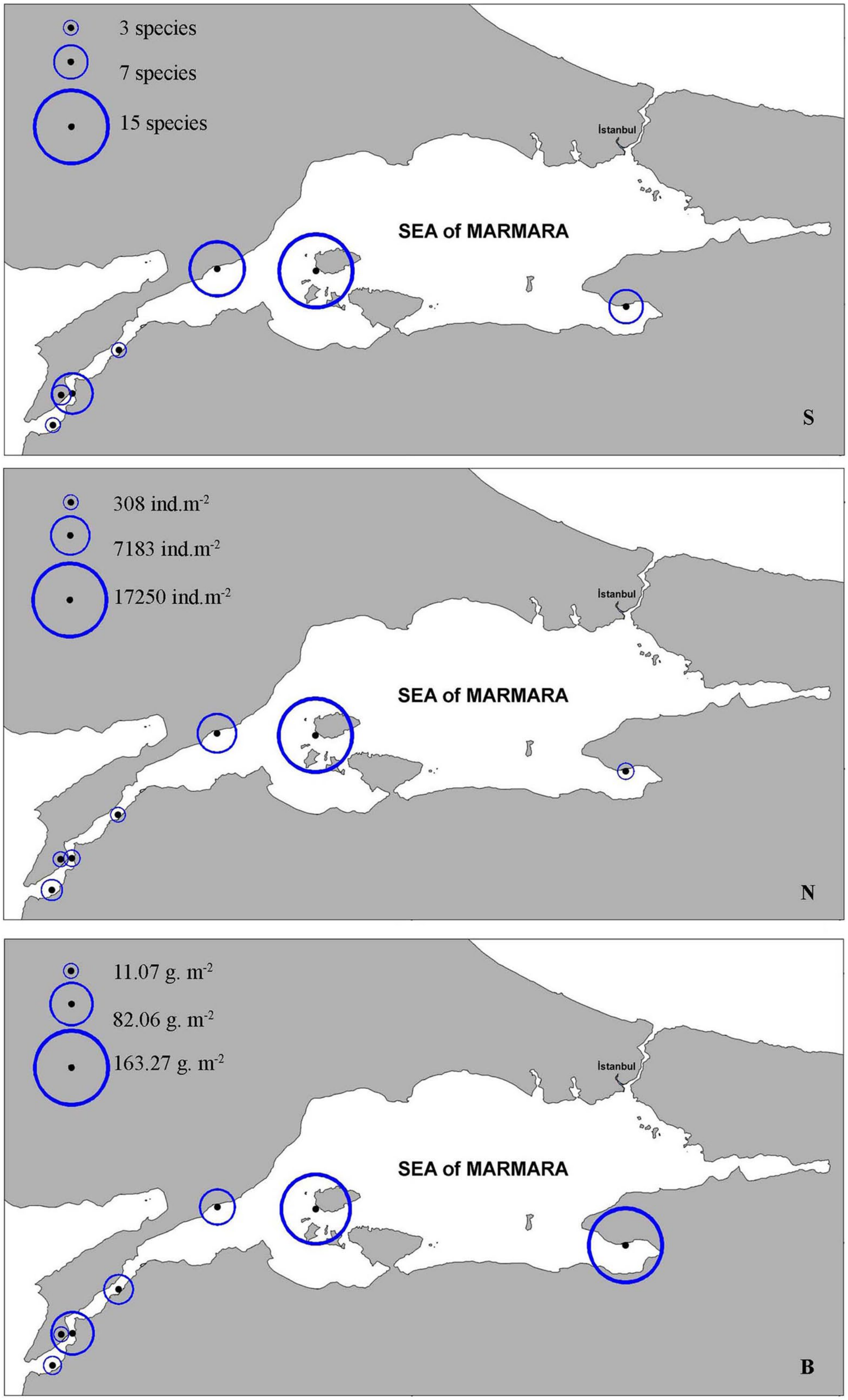


**Fig. 5** Minimum and maximum numbers of species, individuals (per $m^{-2}$) and wet weight values calculated for each station

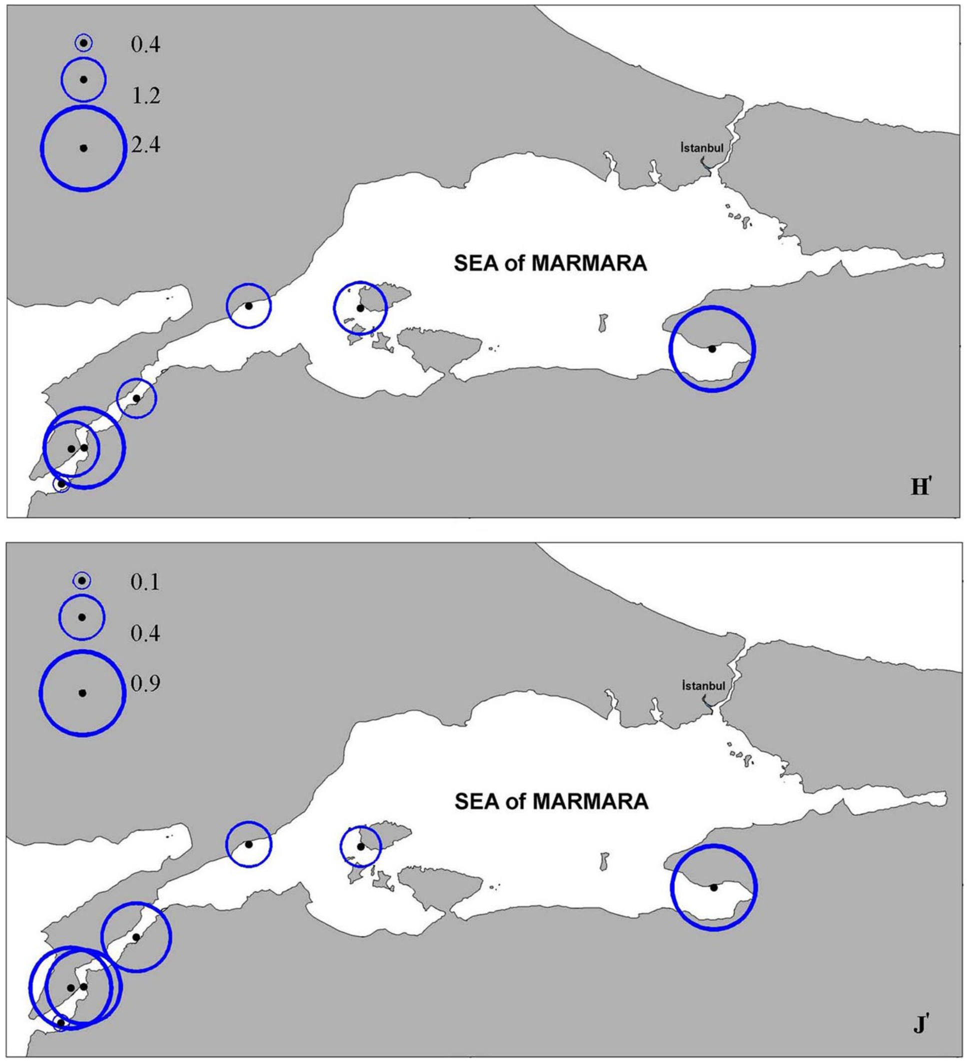


**Fig. 6** Minimum and maximum values of evenness and diversity indices were calculated for each station

($F = 2.658$, $p = 0.002$). CCA axes 1 and 2 clarified 36.2% and 33.8% of the relationship between species and environment, respectively (amounting to 70% in total) (Table 4). The distribution of *S. adansonii* was positively correlated with Chl-a, and negatively correlated with total nitrogen. *Bittium reticulatum* was negatively correlated with Chl-a and positively with total nitrogen (Fig. 7). The content of Chl-a exhibited a strong correlation with the first axis, whereas the concentrations of salinity, phosphorus Chl-a, and dissolved oxygen displayed correlations with the second axis (Table 4).

**Table 3** Pearson's correlation coefficients between the community parameters and environmental variables with statistically important values are indicated and bold ($p < 0.05$)

| | Number of species | Number of specimens | Biomass | Diversity Index | Evenness Index |
|---|---|---|---|---|---|
| **Salinity** | -0.52 | -0.45 | -0.66 | -0.23 | -0.17 |
| **Temperature** | 0.70 | 0.55 | 0.03 | 0.16 | -0.12 |
| **Oxygen** | -0.04 | -0.12 | -0.44 | 0.05 | -0.06 |
| **pHins** | 0.75 | 0.49 | 0.60 | 0.48 | 0.27 |
| **Chla** | -0.30 | -0.48 | -0.41 | 0.35 | 0.43 |
| **Total nitrogen** | 0.04 | 0.03 | 0.71 | 0.32 | 0.13 |
| **Phosphorus** | **0.86** | 0.72 | 0.36 | 0.10 | -0.21 |
| **Silicate** | -0.64 | -0.75 | 0.10 | 0.42 | 0.55 |

**Table 4** The results of the canonical correspondence analysis with statistically important values are bold and marked (p < 0.05)

| Environmental variables | Axis 1 | Axis 2 |
|---|---|---|
| Salinity | 0.1311 | **0.9462** |
| Temperature | -0.3217 | -0.1982 |
| Oxygen | -0.1950 | **0.7910** |
| Chlorophyll a | **-0.4209** | **0.8585** |
| Total nitrogen | 0.1672 | -0.3317 |
| Phoshorus | -0.1305 | **-0.6914** |
| Silicate | -0.0426 | 0.4374 |
| Eigenvalues | 0.671 | 0.626 |
| Species-environment correlations | 0.984 | 0.965 |
| Cumulative percentage variance of species data | 18.3 | 35.4 |
| Cumulative percentage variance of species-environment data | 36.2 | 70 |

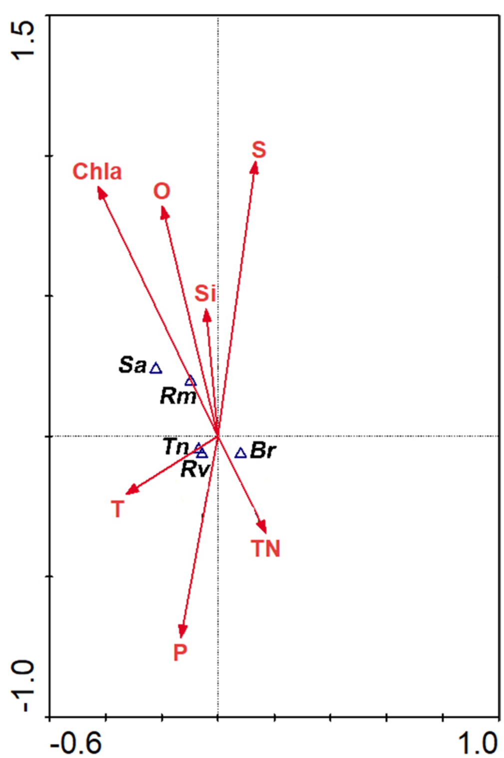


**Fig. 7** Biplot generated from the CCA on the cumulative abundance of all species in the samples and environmental variables (arrows): S: salinity; O: dissolved oxygen; T: temperature; TN: total nitrogen; Chl a: Chlorophyll a; Si: silicate; P: phosphorus; (species): Sa: *Steromphala adansonii*; Tn: *Tritia neritea*; Rm: *Rissoa membranacea*; Rv: *Rissoa ventricosa*; Br: *Bittium reticulatum*

## Discussion

Among the 74 identified taxa obtained through this study, *H. tuberculata*, *O. macilenta*, and *T. rugulosus* have not been encountered in previous studies conducted in the Sea of Marmara. *Haliotis tuberculata*, which was listed as a vulnerable category in the 2019 IUCN Red List of Threatened Species, was collected only at one station (St. 1) in the present study and it was previously documented at İztuzu beach on Turkish Aegean coasts by Aartsen and Kinzelbach (1990) and at Taşucu on Turkish Levantine Sea by Buzzurro and Greppi (1996). Additionally, another species, *O. macilenta*, which was also collected at one station (St. 26) only, was known from the Gulfs of İskenderun and Fethiye (Turkish Levantine Sea) (Bitlis-Bakır and Öztürk 2016) and Turkish Aegean coasts (Demir 2003). The vermetid gastropod, *T. rugulosus,* which is the another new addition to the molluscan fauna in the Sea of Marmara, was previously recorded in the İskenderun Gulf by Çevik and Sarıhan (2004) and along the Aegean coast of Türkiye (Demir 2003).

Considering the number of species (55 species) collected from the *P. oceanica* meadow at 3 stations and 35 species reported from *Z. marina* beds at 5 sampling sites in the present study, this was in agreement with 57 molluscs determined from *P. oceanica* beds in Porto Conte coasts (Italy) (Russo et al. 1991), 57 species stated in Giglio island (Italy) (Martini et al. 2000), and 65 molluscs recorded from Pianosa island (Tuscan Archipelago) (Bedini et al. 2015). Moreover, *R. ventricosa* and *B. reticulatum* reported by Russo et al. (1991) were also similarly dominant and characteristic species in this study. On the other hand, the total number of species count in the current study (73 species) was lower than the number of mollusc species encountered on the rhizomes and the leaves of *P. oceanica* beds (178 and 38, respectively) in Cabo de Palos coasts (Spain) by Templado (1984), 124 mollusc species observed by Beqiraj et al. (2008), who studied the benthic macrofauna of *P. oceanica* in the coasts of Albania (Adriatic and Ionian Sea), 178 molluscs recorded at *P. oceanica* beds in southern Spain by Urra et al. (2011), and 88 mollusc species on the rhizomes and 14 molluscs on the leaves of *P. oceanica* were reported from the Tyrrhenian Sea by Albano and Sabelli (2012). This may be due to the rhizome stratum which have not extensive of hollow spaces on the *P. oceanica* in the Sea of Marmara. Conversely, 47 species were mentioned by Belgacem et al. (2013) associated with *P. oceanica* on the Cap-Zebib coasts (Tunisia) was lower than the quantity of species reported in the current investigation. The molluscan assemblage (118 mollusc species) of *Z. marina* beds in southern Spain reported by Rueda et al. (2008) and (80 mollusc species) by Arroyo et al. (2006) were not in parallel with the findings (35 species) in the present study. Although, it was compatible with 34 molluscs which were found in seagrass beds (*C. nodosa*, *Z. marina*, *Z. noltei*) in the Adriatic Sea by Sfriso et al. (2001). The difference in results obtained in researches on phanerogams associated with mollusc species may also be due to different sampling techniques.

Furthermore, trophic analyses and feeding guilds of molluscs as well as the molluscan assemblage associated with phanerogam meadows have been mentioned in a few studies in Mediterranean Sea (Gambi et al. 1992; Rueda et al. 2009). Within the Gulf of Naples (Italy), 87 mollusc species and several invertebrate groups associated with *P. oceanica* were reported by Gambi et al. (1992). Herbivore-deposit feeders were the most dominant group in all seasons. *Rissoa italiensis* Verduin, 1985, *R. violacea* and *A. lineata* from the family Rissoidae and *B. latreilii* from the family Cerithiidae provided the highest contributions to the herbivores-deposit feeders (Gambi et al. 1992). Correspondingly, *B. reticulatum*, *R. ventricosa*, *R. membranacea*, and *A. discors* were the dominant and frequent species, while the family Rissoidae had the greatest species diversity in this study. One hundred sixty two (162) molluscs were reported from *Z. marina* beds in the Sea of Alboran by Rueda et al. (2009), who similarly revealed that Rissoidae, Veneridae, and Mytilidae were the best represented families, and *R. membranacea* was an abundant epifaunal species. The findings of this study align with previous research conducted at the eastern Ligurian Sea by Vetere et al. (2006) and the Sea of Alboran by Urra et al. (2011). *Bittium reticulatum* and *M. galloprovincialis* were reported as dominant and frequent species (Vetere et al. 2006; Urra et al. 2011). Rissoidae, Mytilidae, and Veneridae presenting with the highest amount of species recorded in the present study, agree with findings of Beqiraj et al. (2008) on the Albanian coasts, Rueda et al. (2008), and Urra et al. (2011; 2013) in the Alboran Sea.

When compared with other parts of the Mediterranean Sea, the number of studies in relation to phanerogams associated with molluscan fauna is inadequate in the Turkish coasts and the Eastern Mediterranean Sea (Çınar et al. 1998; Doğan et al. 2013; Holzknecht and Albano 2022). Seven Bivalvia species with some zoobenthic organisms were detected in *Z. marina* beds at three stations in Gulbahce Bay (Aegean coasts of Türkiye) by Çınar et al. (1998). A total of 251 mollusc species on *P. oceanica* meadows were identified in the study by Doğan et al. (2013), who reviewed studies conducted along the coasts of Türkiye. In parallel with the results of this study, it was mentioned by Doğan et al. (2013) that Rissoidae and Veneridae were the most dominant families. On the Cretan coasts, 19 mollusc species on the leaves and 108 molluscs on the rhizome stratum of *P. oceanica* beds were determined at four different depths, and the species were classified based on their feeding guilds in all seasons by Holzknecht and Albano (2022). *Bittium reticulatum* was declared the most abundant species by Holzknecht and Albano (2022) and this finding is in agreement with the present study.

In the Sea of Marmara, the number of previous studies comparable to the present study is quite low, and they report the benthic invertebrates of *P. oceanica* and *Zostera* spp. meadows in the region (Ostroumoff 1896; Aslan-Cihangir and Ovalis 2013; Öztürk 2014; Artüz et al. 2018). Ostroumoff (1896) stated 278 mollusc species and many invertebrate species from various biotopes such as *Zostera* spp., soft substratums, stones, and gravel in the Sea of Marmara. Subsequently, 283 molluscs were recorded from several biotopes (soft bottoms, *Caulerpa racemosa*, gravel, stone, *M. gallopravincialis*), including *P. oceanica* in the Dardanelles strait by Aslan-Cihangir and Ovalis (2013). Later, Öztürk (2014) reported heterobranchia species from the coasts of Türkiye, and 14 of them were identified from *P. oceanica* in the Marmara Sea. Additionally, Artüz et al. (2018) reported 52 opisthobranchs from 50 stations in the Sea of Marmara covering several biotopes also including phanerogams.

In the present study, the molluscan species associated with phanerogams inhabiting the Marmara Sea are examined comprehensively. Among the 74 identified mollusc species, *H. tuberculata*, *O. macilenta*, and *T. rugulosus* were encountered for the first time in the region. This study will guide future extensive studies on the phanerogams, which have recently been declared to be under protection.

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## Declarations

**Ethical Approval** It is not applicable.

**Competing Interests** The authors declare no competing interests.

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