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ORIGINAL ARTICLE

Composition, abundance and biomass of mesozooplankton in the southwestern Black Sea along the coast of İğneada, Turkey

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Abstract

The qualitative and quantitative structure of mesozooplankton assemblages in the southwestern Black Sea region along the coast of İğneada, Kırklareli Province were assessed and described. The study was conducted on 22 November 2012, 17 May 2013, 13 July 2013 and 4 October 2013. Samples were collected from nine stations using a plankton net via vertical boat hauls. In total, 30 mesozooplankton taxa were identified. The mean mesozooplankton abundance values ranged from 3890.84 ± 2250.04 to 13643.40 ± 1660.55 individuals (ind.) m^{-3}, whereas the biomass values ranged from 26.91 ± 5.4 to 95.76 ± 29.31 mg m^{-3}. The most abundant taxa were *Oithona davisae* (2871.20 ± 436.24 ind. m^{-3} in November 2012 and 1310.83 ± 157.222 ind. m^{-3} in October 2013), Copepoda nauplii (4007.08 ± 3513.07 ind. m^{-3} in May 2013) and Bivalvia larvae (11118.41 ± 4798.74 ind. m^{-3} in July 2013). The taxa with the highest biomass were *Parasagitta setosa* (7.43 ± 2.32 mg m^{-3} in November 2012 and 33.52 ± 9.45 mg m^{-3} in October 2013), Polychaeta larvae (20.87 ± 9.63 mg m^{-3} in May 2013) and Bivalvia larvae (55.59 ± 23.99 mg m^{-3} in July 2013). Abundance and biomass of the species/groups of mesozooplankton are presented as mean ± standard error of the mean (SEM). There were no significant differences among the seasons and stations for either total abundance or biomass; however, there was a significant monthly variation in the mesozooplankton assemblages. Changes in the abundance and biomass of mesozooplankton were dependent on the physical environment.

Keywords İğneada · Southwestern Black Sea · Turkey · Mesozooplankton · Abundance · Biomass

Introduction

Pelagic ecosystem monitoring is of great importance to evaluating the health of marine ecosystems and making predictions about their future. Since mesozooplankton (200–2000 µm) are a major trophic link that ensure energy transfer from primary producers (phytoplankton) to the upper trophic levels (whales, seabirds, fishes humans), it is important to examine and understand their abundance and distribution. Mesozooplankton are very sensitive to hydroclimatic factors. Therefore, variation in the abundance and composition of mesozooplankton due to climatic factors can have an important impact on the upper trophic levels and fisheries (Lenz 2000; Marcus 2004; Hays et al. 2005).

The history of research on planktonic fauna in the Black Sea along Turkish coasts is relatively recent. The earliest study on zooplankton in Turkey's Black Sea was conducted by Demir (1954) between 1952 and 1953. Previous studies on mesozooplankton species composition, abundance and biomass of the Turkish Black Sea primarily focussed on the eastern region (Einarsson and Gürtürk 1959; Ünal 2002; Bat et al. 2007; Özdemir and Ak 2012; Özdemir Şen 2013; Deniz 2013; Ateş 2014; Yıldız and Feyzioğlu 2014; Üstün et al. 2016, 2018) and around the Bosporus Strait (Isinibilir 2009; Isinibilir et al. 2011).

The town of İğneada is in the northwestern part of Turkey near the border of Bulgaria. The land area of İğneada has been preserved as a national park since 2007 to conserve the coastal sand dunes and floodplain forestland (Longoz forests). This area is considered to be one of the most biologically and ecologically important of Turkey because of its very diverse ecosystems, which comprise forests, lakes, reed wetlands, sand dunes and sea life (Ministry of Forestry and Water Affairs 2007 - http://igneada.tabiat.gov.tr/; Accessed July 2018). İğneada is also bordered by the Rezova region, a marine protected area in

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Bulgaria (Begun et al. 2012). Öztürk et al. (2013) suggested that a marine area close to İğneada should also be declared a nationally protected area because the adjacent terrestrial region is designated as such. The İğneada marine area has a rich biodiversity and is a breeding ground for many commercial fish species. In addition, it is located close to a Bulgarian designated marine preservation area.

The objective of this study was to provide baseline mesozooplankton data of the Black Sea (İğneada area) in terms of taxa composition, abundance, biomass, and physical parameters and explore relationships among those variable. This study is valuable since it is the first that characterizes mesozooplankton biodiversity in the İğneada region (Western Black Sea, Turkey) and will provide a basis for future research. There is a need for more research on zooplankton in marine ecosystems to promote its understanding and to conserve its biodiversity by the monitoring of any changes to zooplankton populations.

Materials and methods

İğneada is a coastal port town located in the southwestern region of the Black Sea in the Demirköy District of the Kırklareli Province. It is in the north of the Marmara region on the outskirts of the Istranca (Yıldız) Mountains bordering the Black Sea. The Black Sea is to the east and Bulgaria is to the north of İğneada. İğneada is located 15 km away from Bulgaria and 26 km away from the Demirköy District. The Black Sea climate is dominant in İğneada and its surroundings, which have a rich biodiversity and diverse ecosystem (Özyavuz 2008; Bozkaya 2013). Since the area is little populated (TUIK 2018), anthropogenic pressures there are very limited.

The study was performed in the Black Sea, close to İğneada, Kırklareli Province (NW Turkey), at nine stations where samples were collected from three seawater depths (5, 10 and 20 m). Sampling was conducted on 22 November 2012, 17 May 2013, 13 July 2013 and 4 October 2013 (Table 1; Fig. 1).

The temperature, salinity and dissolved oxygen concentrations were measured at each station at a depth of 1 m of seawater using a YSI 6600 MDS model multi-parameter meter.

The mesozooplankton samples were collected within a column extending from the sea bottom to the sea surface via vertical tows using a plankton net with a mesh size of 112 μm and a mouth area size of 0.25 m^2. Following the collection, the samples were immediately fixed in borax-buffered formaldehyde-sea water solution to a final concentration of 4%.

Two subsamples from each sample were taken from a container of known volume using a Stempel pipette (1 mL) for the quantitative analyses of mesozooplankton individuals. The identification and count of the mesozooplankton individuals

Table 1 The location and seawater depth of the Black Sea mesozooplankton sampling stations near İğneada, Kırklareli Province (NW Turkey)

Station name	Coordinates	Sampling depth (m)
I-1-1	41°52′10″N–27°59′10″E	5
I-1-2	41°52′05″N–27°59′24″E	10
I-1-3	41°52′13″N–28°00′15″E	20
I-2-1	41°53′25″N–28°00′25″E	5
I-2-2	41°53′04″N–28°00′45″E	10
I-2-3	41°52′24″N–28°01′13″E	20
I-3-1	41°52′50″N–28°02′43″E	5
I-3-2	41°52′39″N–28°02′40″E	10
I-3-3	41°52′14″N–28°02′44″E	20

in the subsamples were conducted under a stereomicroscope with a zooplankton counting apparatus (Bogorov Rass Chamber). The samples were investigated for rare and large organisms which were counted and recorded (Postel et al. 2000). The mesozooplankton abundance and biomass results were recorded in individuals per cubic metre (ind. m^{-3}) and mg per cubic metre (mg m^{-3}), respectively. The biomass transformations were based on the wet individual weights according to Petipa (1957) and Niermann et al. (1995). Abundance and biomass of the species/groups of mesozooplankton are presented as mean ± standard error of the mean (SEM).

The taxa Cladocera, Copepoda, Appendicularia and Chaetognatha were identified at the species level. All other taxa were identified to phylum, class, or order. Publications on mesozooplankton identification by Bradford-Grieve et al. (1999) and Conway et al. (2003) were used in the identification of the major mesozooplankton groups. The systematic classification and the nomenclature of the mesozooplankton species were determined according to the World Register of Marine Species (WoRMS 2018).

One-way ANOVAs and post hoc Tukey tests were used to determine differences in the abundance and biomass of mesozooplankton across and within seasons and between stations. In addition, the Spearman Rank correlation was used to evaluate correlations of the abundance of mesozooplankton taxa and groups with environmental variables, and the abundance of *Noctiluca scintillans* (SPSS 21 IBM Crop., Armonk, NY, USA). In order to explain the mesozooplankton quantitative data in terms of community assemblage, analyses using, the Shannon–Weaver diversity index (H′), Pielou evenness (J′), and the number of species (S) were performed with the abundance data based on the taxa and groups using PRIMER 5 software. Mesozooplankton species similarities and dissimilarities between stations and months were analysed with the methods nonmetric multidimensional scaling (nMDS) and a hierarchical cluster analysis (CLUSTER), analysis of similarity (ANOSIM) and similarity percentages

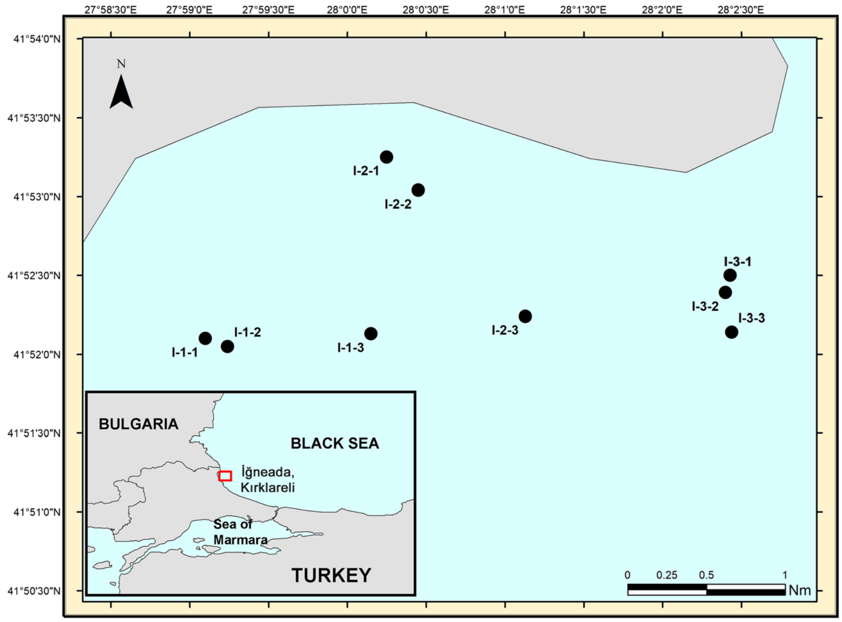

Fig. 1 The location of the Black Sea mesozooplankton sampling stations near İğneada, Kırklareli Province (NW Turkey)

(SIMPER) calculated according to the Bray–Curtis similarity principle using Primer v6 software package. The abundance values of zooplankton species were first log transformed before analysis.

Results

Hydrographic parameters

The seawater temperature was lowest in November 2012 (14.65 °C; Station [St] I-1-1) and highest in July 2013 (24.68 °C; St I-2-3). The salinity varied from 14.87 (May 2013; St I-1-1) to 18.31 ‰ (October 2013; St I-1-1). The dissolved oxygen fluctuated between 7.45 (July 2013; St I-2-1) and 10.39 mg L^{-1} (May 2013; St I-2-3) (Fig. 2).

Abundance, biomass, taxonomic composition and assemblage structure of mesozooplankton

Regionally, the highest means across the nine stations for both mesozooplankton abundance and biomass were recorded in July 2013, whereas the lowest means for abundance and biomass were observed in October 2013 and November 2012, respectively (Fig. 3). The calculated mean abundance and biomass values of mesozooplankton are presented in Table 2. There were no statistically significant differences for both total abundance and biomass among the seasons and stations (F = 1.671 abundance, F = 2.405 biomass; $p > 0.05$).

The mesozooplankton abundance and biomass values varied between 2103 – 8859 ind. m^{-3} and 11–55 mg m^{-3} in November 2012, 1409–51442 ind. m^{-3} and 11–263 mg m^{-3} in May 2013, 2671–43728 ind. m^{-3} and 28–271 mg m^{-3} in July 2013, and 2425–6354 ind. m^{-3} and 25–129 mg m^{-3} in October 2013, respectively (Fig. 4).

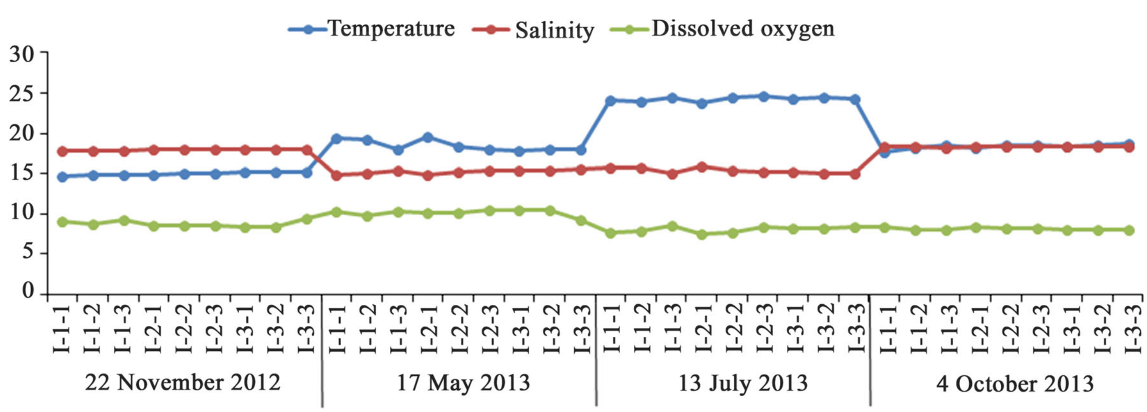

Fig. 2 The seawater temperature (°C), salinity (‰) and dissolved oxygen (mg L^{-1}) at depth of 1 m at sampling stations in the Black Sea near İğneada, Kırklareli Province

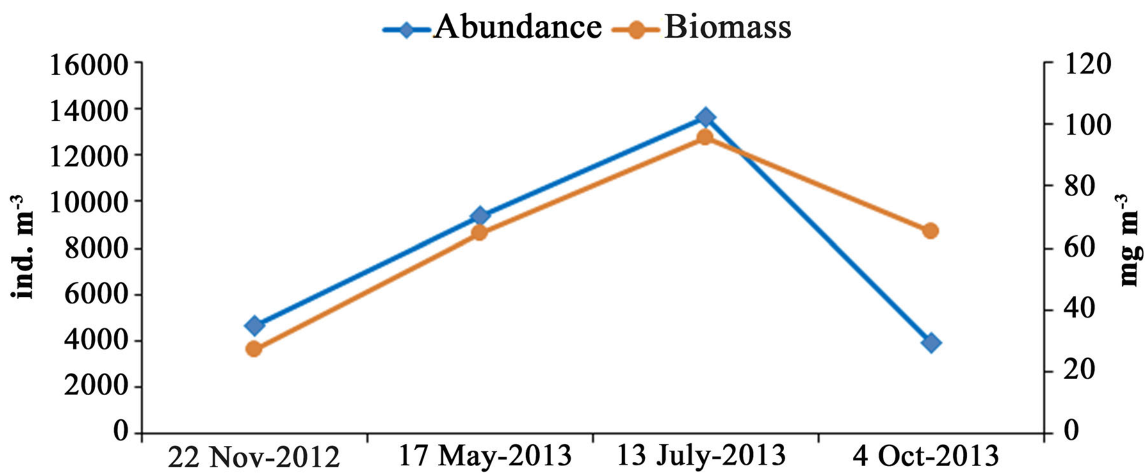

Fig. 3 The mean mesozooplankton abundance (individuals [ind.] m^{-3}) and biomass (mg m^{-3}) values from nine sampling stations (three locations, with sampling at three depths) in the Black Sea near İğneada, Kırklareli Province

In total, thirty mesozooplankton taxa were identified in the Black Sea close to İğneada. Eight species of the subclass Copepoda, four species of the superorder Cladocera, one species of the phylum Chaetognatha, one species of the class Appendicularia, and eleven groups belonging to meroplankton were found in the sampling area (Table 2).

In November 2012, the copepod *Oithona davisae* was detected at a higher abundance and biomass than in the other sampling months, and was the most dominant species at that time. The copepod *Acartia* sp., *Acartia (Acartiura) clausi*, Copepoda nauplii, and Bivalvia larvae were also prominent, whereas *Parasagitta setosa* contributed significantly to mesozooplankton biomass. The Cladocera were represented by only one species, *Penilia avirostris* (Table 2). No statistical differences were found in total abundance and biomass among stations in November 2012 ($F = 0.498$ abundance, $F = 1.595$ biomass; $p > 0.05$).

In May 2013, *Pleopis polyphemoides*, *Acartia* sp., Copepoda nauplii, and Cirripeda and Polychaeta larvae had their highest abundance and biomass values compared with the other sampling months. The Cladocera were only represented by *P. polyphemoides* (Table 2). The total mesozooplankton abundance and biomass values among stations differed significantly in May 2013 ($F = 2.057$ abundance, $F = 3.223$ biomass; $p < 0.05$). The mesozooplankton abundance, at the station I-2-1 differed significantly from the stations I-1-3, I-2-3 and I-3-3 at this time. The biomass at the station I-2-1 also differed significantly from all the other stations ($p < 0.05$). The abundance and biomass values of *P. polyphemoides*, *Parasagitta setosa*, *Acartia* sp., Copepoda nauplii, Bivalvia, Cirripedia, Gastropoda and Polychaeta larvae were found to be relatively high at the station I-2-1 compared with the other stations.

In July 2013, meroplankton was the dominant group in terms of both abundance and biomass. This result was because of the high abundance and biomass of Bivalvia larvae, which were followed by the Gastropoda and Cirripedia larvae. The Cladocera *Pleopis polyhemoides*, and the Copepoda *Oithona davisae* and *Acartia* sp., also had high abundance and biomass at this time. The meroplankton Ascidacea and medusae planula larvae, were encountered only during this sampling period (Table 2). There were no significant differences in the total mesozooplankton abundance and biomass among stations at this time ($F = 0.793$ abundance, $F = 0.981$ biomass; $p > 0.05$).

In October 2013, *Oikopleura* (*Vexillaria*) *dioica*, *Penilia avirostris*, *Parasagitta setosa, Centropages ponticus* and *Paracalanus parvus* had relatively high abundance and biomass values. *P. avirostris* had the highest abundance and biomass values and was most dominant among the Cladocera species. The Cladocera *Evadne spinifera* and the copepod *Oithona similis* were only detected during this month (Table 2). There were no significant differences in the total mesozooplankton abundance and biomass among stations at this time ($F = 0.676$ abundance, $F = 0.485$ biomass; $p > 0.05$).

In terms of relative mesozooplankton abundance, Copepoda was the dominant group in November 2012 (82.03%), May 2013 (57.10%) and October 2013 (81.44%), and meroplankton was the dominant group in July 2013 (88.48%). In terms of relative mesozooplankton biomass, Copepoda had high percentages in November 2012 (48.78%), whereas meroplankton were dominant in May 2013 and July 2013 (67.77 and 72.31%, respectively), and Chaetognatha comprised half of all the biomass in October 2013 (51.39%) (Fig. 5).

The lowest number of taxa was recorded in November 2012 at St I-1-1 (11 taxa or groups) and the highest was recorded in October 2013 at the station I-3-2 (23 taxa or groups). The station I-1-2 in May 2013 had the highest values for both the Pielou evenness and Shannon diversity indeces (0.78 and 3.18, respectively). Conversely, the station I-3-2 in July 2013 had the lowest values (0.16 and 0.71, respectively). This

Table 2 The mean (± SEM), abundance (ind. m^{-3}) and biomass (mg m^{-3}) values of mesozooplankton taxa and groups during this study

	22 November 2012		17 May 2013		13 July 2013		4 October 2013	
	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
Appendicularia								
Oikopleura (*Vexillaria*) *dioica* Fol, 1872	19.90 ± 9.04	0.66 ± 0.27	194.48 ± 59.24	1.46 ± 0.41	1.76 ± 1.19	0.05 ± 0.04	204.39 ± 45.30	2.51 ± 0.38
Cladocera								
Evadne spinifera (P.E. Müller, 1867)	0	0	0	0	0	0	5.80 ± 3.19	0.03 ± 0.01
Penilia avirostris (Dana, 1849)	15.65 ± 4.94	0.44 ± 0.14	0	0	42.38 ± 8.08	1.19 ± 0.23	94.98 ± 16.30	2.70 ± 0.46
Pleopis polyphemoides (Leuckart, 1859)	0	0	305.73 ± 111.72	3.03 ± 1.12	82.15 ± 27.85	0.74 ± 0.25	0.03 ± 0.03	0.0003 ± 0.0003
Pseudevadne tergestina (Claus, 1877)	0	0	0	0	3.43 ± 1.22	0.01 ± 0.005	7.67 ± 1.64	0.04 ± 0.01
Chaetognatha								
Parasagitta setosa (Müller, 1847)	12.74 ± 2.94	7.43 ± 2.32	28.76 ± 19.83	0.58 ± 0.41	56.22 ± 9.19	6.14 ± 0.92	159.26 ± 40.02	33.52 ± 9.45
Copepoda								
***Acartia* sp.	243.88 ± 36.75	1.58 ± 0.29	888.89 ± 196.66	5.74 ± 0.89	232.24 ± 46.32	1.44 ± 0.31	531.35 ± 75.25	3.83 ± 0.85
Acartia (*Acartiura*) *clausi* (Giesbrecht, 1889)	199.29 ± 46.85	4.99 ± 1.17	210.05 ± 42.90	4.49 ± 0.91	29.10 ± 8.63	0.77 ± 0.23	138.63 ± 27.51	3.49 ± 0.67
Acartia (*Acanthacartia*) *tonsa* (Dana, 1849)	2.83 ± 2.83	0.08 ± 0.08	0	0	95.12 ± 17.94	2.56 ± 0.49	0	0
Calanus euxinus (Hulsemann, 1991)	0.17 ± 0.12	0.07 ± 0.06	0	0	0	0	0.42 ± 0.15	0.17 ± 0.11
Centropages ponticus (Karavaev, 1895)	1.78 ± 0.66	0.09 ± 0.03	80.96 ± 41.44	1.26 ± 0.39	10.56 ± 4.54	0.23 ± 0.11	170.08 ± 15.52	3.33 ± 0.43
Oithona davisae (Ferrari F.D. & Orsi, 1984)	2871.20 ± 436.24	5.14 ± 0.73	114.93 ± 63.68	0.12 ± 0.06	334.90 ± 29.46	0.75 ± 0.08	1310.83 ± 157.22	5.47 ± 2.63
Oithona similis (Claus, 1866)	0	0	0	0	0	0	6.26 ± 3.00	0.01 ± 0.01
Paracalanus parvus (Claus, 1863)	90.59 ± 19.28	0.68 ± 0.11	32.84 ± 5.43	0.23 ± 0.04	0	0	544.43 ± 46.06	4.78 ± 1.28
Pseudocalanus elongatus (Boeck, 1865)	0	0	0	0	0.06 ± 0.06	0.002 ± 0.002	3.40 ± 3.40	0.13 ± 0.13
Unidentified Copepoda	3.59 ± 2.40	0.11 ± 0.07	0.31 ± 0.16	0.009 ± 0.005	398.05 ± 116.69	12.34 ± 3.62	32.84 ± 9.61	1.02 ± 0.30
Unidentified Copepoda nauplii	397.74 ± 82.35	0.40 ± 0.08	4007.08 ± 3513.07	4.01 ± 3.51	267.43 ± 37.08	0.27 ± 0.04	428.17 ± 49.87	1.01 ± 0.56
Unidentified Copepoda single eggs	0	0	0	0	18.43 ± 9.73	0.02 ± 0.01	2.12 ± 1.50	0.002 ± 0.001
Meroplankton								
Actinotroch larvae	0.57 ± 0.57	0.08 ± 0.08	0	0	0.11 ± 0.11	0.001 ± 0.001	0.25 ± 0.12	0.04 ± 0.02
Ascidiacea larvae	0	0	0	0	0.11 ± 0.11	0.002 ± 0.002	0	0
Bivalvia larvae	728.95 ± 163.48	3.64 ± 0.82	2101.34 ± 840.63	10.51 ± 4.20	11118.41 ± 4798.74	55.59 ± 23.99	93.84 ± 26.09	0.49 ± 0.12
Cirripedia larvae	8.01 ± 2.84	0.13 ± 0.05	753.04 ± 392.46	11.79 ± 6.14	392.16 ± 170.96	6.27 ± 2.66	14.89 ± 3.21	0.38 ± 0.11
Cyphonautes larvae	0	0	0	0	32.44 ± 21.01	0.04 ± 0.02	4.05 ± 2.75	0.005 ± 0.004
Decapoda larvae	0.14 ± 0.11	0.01 ± 0.01	1.70 ± 0.68	0.11 ± 0.04	5.07 ± 0.98	0.31 ± 0.06	3.62 ± 0.99	0.22 ± 0.06
Gastropoda larvae	19.11 ± 4.25	0.21 ± 0.05	73.60 ± 37.06	0.74 ± 0.37	470.94 ± 130.73	5.13 ± 1.42	115.50 ± 25.98	1.38 ± 0.27
Medusae planula larvae	0	0	0	0	0.06 ± 0.06	0.0003 ± 0.0003	0	0
Microniscus sp.	3.60±	0.18 ± 0.14	0	0	0	0	0.20 ± 0.13	0.01 ± 0.01
Polychaeta larvae	26.19 ± 8.07	0.10 ± 0.31	549.19 ± 253.53	20.87 ± 9.63	49.88 ± 13.10	1.90 ± 0.50	17.83 ± 6.24	0.67 ± 0.24
Fish egg	0.06 ± 0.06	0	0.06 ± 0.06	0	2.01 ± 0.32	0	0	0
Fish larvae	0.17 ± 0.11	0	0.06 ± 0.06	0	0.40 ± 0.14	0	0	0
Total Mesozooplankton Mean m^{-3}	4646.14 ± 2763.94	26.91 ± 5.40	9342.90 ± 1620.31	64.94 ± 25.57	13643.40 ± 1660.55	95.76 ± 29.31	3890.84 ± 2250.04	65.24 ± 10.19
Dinoflagellata								
Noctiluca scintillans (Macartney) Kofoid & Swezy, 1921	615.00 ± 219.22	54.12 ± 19.29	7176.22 ± 1390.42	631.51 ± 122.4	708.51 ± 317.80	62.35 ± 27.97	29.72 ± 5.33	2.57 ± 0.50

***Acartia* sp. represents the sum of copepodit4 + copepodit3 + copepodit2 + copepodit1

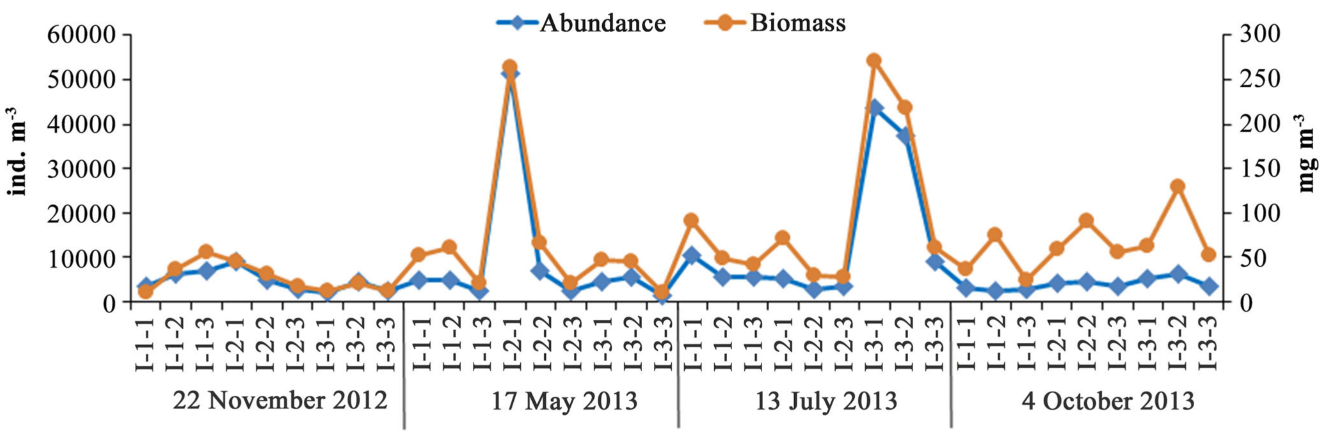

Fig. 4 The abundance (ind. m^{-3}) and biomass (mg m^{-3}) values of mesozooplankton at sampling stations in the Black Sea near İğneada, Kırklareli Province

decrease in diversity is because of the dominance of Bivalvia larvae sampled at the time (Fig. 6).

The mesozooplankton assemblage (based on abundance) displayed significant seasonal variations in the Black Sea along the İğneada coast. The nMDS and Cluster analyses, indicated that the data were aggregated by sampling dates (Fig. 7). The assemblage similarity and dissimilarity within and between the sampling dates was tested by the SIMPER and ANOSIM analyses. The ANOSIM test revealed a statistically significant difference in the community assemblage between sampling dates ($R = 0.988$, $p = 0.001$). The SIMPER analysis showed that the lowest intra-group similarity value (48.66%) was detected in May 2013, whereas the highest (76.22%) was detected in October 2013. For these sampling dates, the species that contributed the most to mesozooplankton abundance were *Oithona davisae*, Bivalvia larvae, *Acartia* sp., Copepoda nauplii, and *Paracalanus parvus* (Table 3). An examination of the mean dissimilarity percentages between the sampling dates, indicated that the lowest rate was between November 2012 and October 2013 (47.74%) and the highest rate was between July 2013 and October 2013 (79.98%). The SIMPER analysis showed that the taxa most responsible for the dissimilarity between the sampling dates were *O. davisae*, Bivalvia larvae, and Copepoda nauplii (Table 3).

Relationships of mesozooplankton abundances and environmental variables

The total abundance of mesozooplankton was negatively correlated with salinity ($p < 0.05$), whereas the total biomass was positively correlated with temperature ($p < 0.01$) and was negatively correlated with dissolved oxygen ($p < 0.05$). There were no correlations found of the abundance of *N. scintillans* and the total abundance and biomass of mesozooplankton. However, negative correlations were found between the abundance of *N. scintillans* and the abundances of the Cladocera species (except *Pleopis ployphemoides*), Copepoda species (*Calanus euxinus, Oithona davisae, Oithona similis* and *Paracalanus parvus*) and the Chaetognatha, *Parasagitta setosa*. A positive correlation was found between the abundance of *N. scintillans* and the abundances of *P. ployphemoides*, Bivalvia larvae, Cirripedia larvae and Polychaeta larvae. While no correlation was found between the abundances of *N. scintillans* and temperature, which is an important environmental parameter, a negative correlation with salinity and a positive correlation with oxygen were evidenced. *Oithona davisae*, *Acartia* sp. and Bivalvia larvae were found to be the most abundant groups in the Black Sea of the İğneada region. *O. davisae*

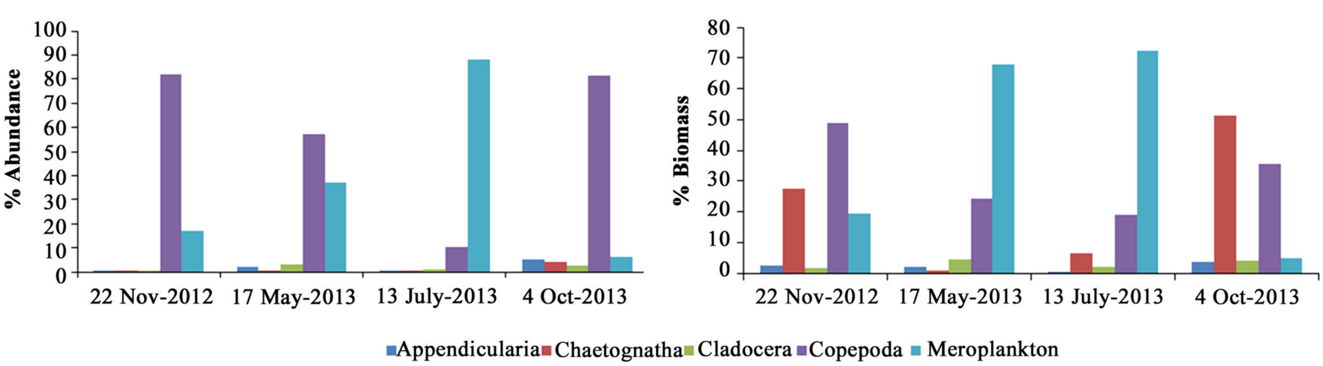

Fig. 5 The relative abundance and biomass of the mesozooplankton groups in the Black Sea of the İğneada region

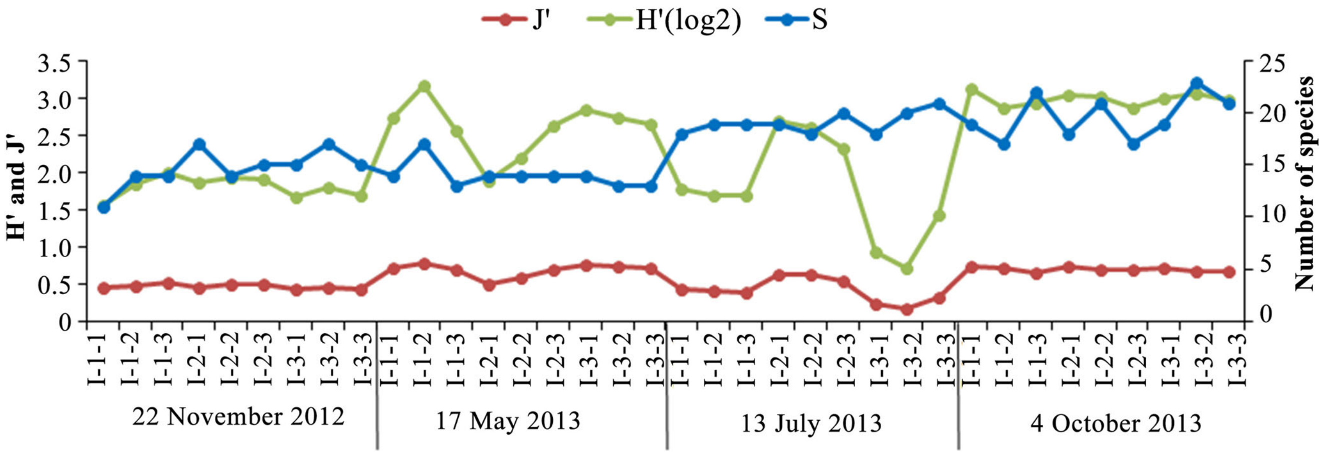

Fig. 6 The Shannon diversity index (H′), Pielou evenness index (J′) and number of species (S) for mesozooplankton for each month and sampling station

abundance was negative correlated with temperature and *Noctiluca scintillans* abundance was positively correlated with salinity ($p < 0.01$). The abundance of *Acartia* sp. was found to be positively correlated with dissolved oxygen ($p < 0.05$). Bivalvia larval abundance was positively correlated with both temperature ($p < 0.05$) and *N. scintillans* abundance ($p < 0.01$), but negatively correlated with salinity ($p < 0.01$) (Table 4).

Fig. 7 The cluster and non-multidimensional scaling (nMDS) ordinations of the mesozooplankton assemblages

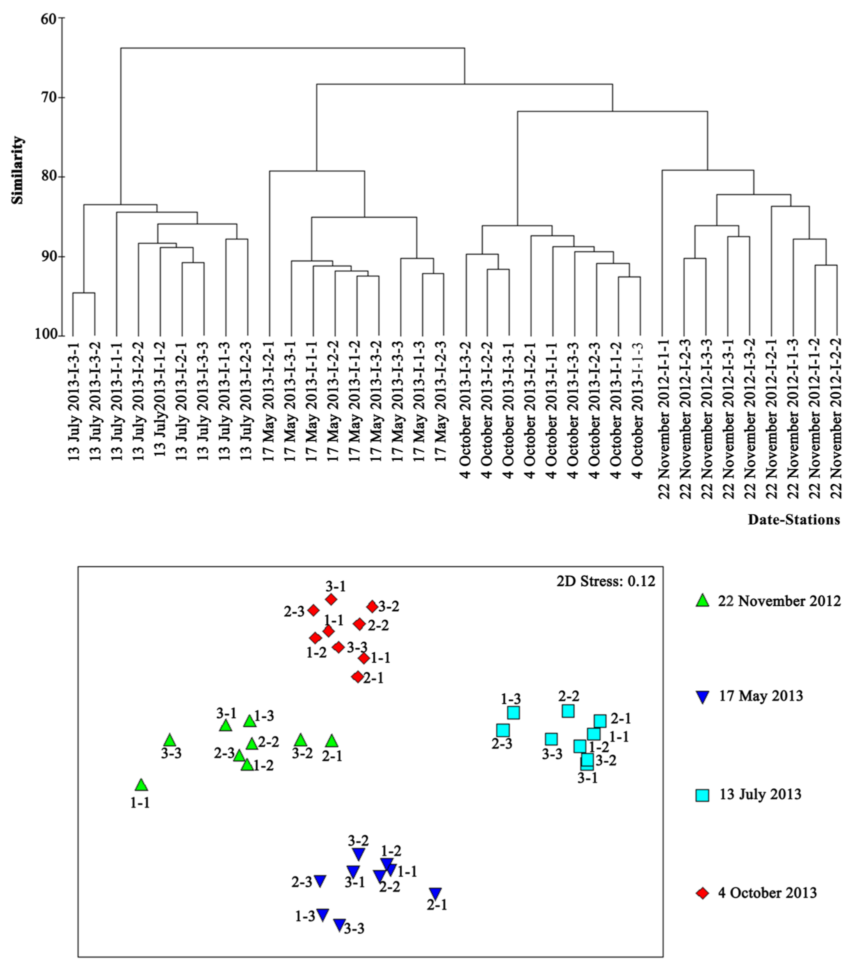

Table 3 The results of the similarity percentages (SIMPER) analyses indicating the similarity and the dissimilarity in the mesozooplankton assemblage between sampling dates

	Species	Average similarity	Similarity/SD	Contribution%
November 2012 (Average similarity 69.56%)	*Oithona davisae*	46.38	4.56	66.67
	Bivalvia larvae	9.28	2.71	13.34
May 2013 (Average similarity 48.66%)	Bivalvia larvae	15.17	1.92	31.18
	Acartia sp.	11.79	1.60	24.24
	Copepoda nauplii	6.63	1.69	13.63
July 2013 (Average similarity 48.98%)	Bivalvia larvae	33.06	1.72	67.50
	Oithona davisae	3.33	1.49	6.80
October 2013 (Average similarity 76.22)	*Oithona davisae*	26.66	5.64	34.98
	Paracalanus parvus	12.73	5.39	16.70
	Acartia sp.	10.59	4.68	13.89
		Average dissimilarity	Dissimilarity/SD	Contribution%
November 2012–May 2013 (Average dissimilarity 71.05%)	*Oithona davisae*	29.30	2.30	41.24
	Bivalvia larvae	10.36	1.17	14.5
November 2012–July 2013 (Average dissimilarity 75.62%	Bivalvia larvae	40.35	1.59	53.36
	Oithona davisae	20.14	1.80	26.63
November 2012–October 2013 (Average dissimilarity 47.74%)	*Oithona davisae*	17.75	1.64	37.17
	Bivalvia larvae	6.88	1.72	14.42
May 2013–July 2013 (Average dissimilarity 68.18%)	Bivalvia larvae	35.63	1.36	52.25
	Copepoda nauplii	7.88	0.50	11.56
May 2013–October 2013 (Average dissimilarity 69.29%)	*Oithona davisae*	14.63	2.09	21.12
	Bivalvia larvae	14.61	1.61	21.09
July 2013–October 2013 (Average dissimilarity 79.98%)	Bivalvia larvae	46.79	2.11	58.50
	Oithona davisae	8.63	1.61	10.79

Discussion

The mesozooplankton assemblage of the Black Sea near İğneada was characterized in terms of taxa composition, seasonal abundance, biomass and environmental parameters and relationship among these variables were explored, in an effort to understand the mesozooplankton biodiversity in the region.

The mesozooplankton abundance and biomass values recorded in this study were found to be much higher when compared with those of the Sinop (Ünal 2002; Üstün et al. 2016, 2018), Samsun (Deniz 2013) and Trabzon (Özdemir and Ak 2012) areas, which form part of Turkey's Black Sea coastal region. The relatively higher values in the İğneada region can be attributed to the higher number of sampling stations (only one station was used for the other areas). Furthermore, the seawater depth was shallower in the İğneada region than in the other areas (approximately 50 m for other areas). Coastal waters are areas where many fish and invertebrate species perform many ecological and biological functions, such as nesting, feeding, laying eggs and hiding from predators (Mann 2000). In this study, meroplankton (planktonic larvae produced by many bottom living marine organisms) and Copepoda nauplii were observed to be more abundant compared with other regions, which supports our hypothesis. The species *Oithona davisae* made the most significant contribution to the high mesozooplankton and copepod abundance and biomass values in our study area compared to other regions (Sinop, Samsun and Trabzon), this species was defined as *Oithona brevicornis* in 2001 in the Black Sea (Zagorodnyaya 2002). Although this species can be observed in the Black Sea plankton population year-round, it is more abundant in the autumn (Selifonova 2009; Mihneva and Stefanova 2013; Altukhov et al. 2014; Seregin and Popova 2016; Yıldız et al. 2017). In our study, *O. davisae* was observed at all stations and was found to have a higher abundance than the other copepod species (except in May 2013 when *Acartia* sp. was dominant). It was identified at all stations throughout the sampling period, with maximum abundance and biomass values in November 2012 and October 2013. The present study shows that this species, which was detected for the first time in Sinop in the autumn of 2009 in the Black Sea along Turkish coasts (Üstün and Terbıyık Kurt 2016). Three years after its initial detection, it appears that *O. davisae* has formed a permanent and dominant population.

In the present study, the contribution of *Calanus euxinus*, *Pseudocalanus elongatus* and *Oithona similis* species to the Copepoda population was lower than that of previous studies (Ünal 2002; Vinogradov et al. 2011; Üstün et al. 2016, 2018),

Table 4 Correlations of the abundances of mesozooplankton taxa and groups with environmental parameters and the abundance of *Noctiluca scintillans*

	Temperature	Salinity	Dissolved oxygen	*Noctiluca scintillans*
Total abundance	.302	−.395*	−.081	.188
Total biomass	.527**	−.116	−.358*	−.135
Oikopleura (Vexillaria) dioica	−.263	.279	.285	.094
Cladocera	.579**	−.411*	.007	.175
Evadne spinifera	.037	.668**	−.480**	−.611**
Penilia avirostris	.313	.510**	−.801**	−.765**
Pleopis polyphemoides	.525**	−.864**	.346*	.636**
Pseudevadne tergestina	.491**	.340*	−.662**	−.647**
Parasagitta setosa	.505**	.247	−.605**	−.511**
Copepoda	−.528**	.496**	.031	−.134
Acartia (Acartiura) clausi	−.527**	.147	.510**	.257
Acartia (Acanthacartia) tonsa	.653**	−.409*	−.494**	−.049
Acartia sp.	−.069	−.072	.413*	.243
Calanus euxinus	−.171	.447**	−.251	−.373*
Centropages ponticus	.243	.178	−.041	−.220
Oithona davisae	−.502**	.632**	−.270	−.453**
Oithona similis	.087	.505**	−.357*	−.427**
Paracalanus parvus	−.494**	.775**	−.028	−.415*
Pseudocalanus elongatus	.161	.121	−.326	−.145
Copepoda nauplii	−.120	−.044	.251	.219
Copepoda single eggs	.476**	−.056	−.480**	−.055
Meroplankton	.491**	−.853**	.154	.531**
Bivalvia larvae	.410*	−.817**	.152	.501**
Cirripedia larvae	.679**	−.750**	.092	.454**
Decapoda larvae	.752**	−.167	−.507**	−.351*
Gastropoda larvae	.776**	−.196	−.605**	−.252
Polychaeta larvae	.166	−.547**	.306	.636**
Noctiluca scintillans	−.102	−.649**	.657**	

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

and its availability in plankton samples was rather limited. All three species were identified in the plankton samples of October 2013. In addition, *C. euxinus* was present in November 2012, and *P. elongatus* was present in July 2013, albeit at lower abundances. In the Black Sea, these plankton species are abundantly present in the colder months (Vinogradov et al. 1992; Arashkevich et al. 1998; Ünal 2002; Deniz and Gönülol 2014; Yıldız and Feyzioğlu 2014; Üstün et al. 2016) and exhibit diel vertical migration by concentrating in suboxic waters containing low concentrations of oxygen at the bottom (Erkan et al. 2000; Besiktepe 2001; Stefanova et al. 2012). This may explain their lower abundance and biomass values and the lower presence in our study area, which is rather shallow compared with other study areas. The available data in our study characterises the general habitat of these species.

The presence of the Cladocera at sea is intermittent (temporal distribution), and is known to be controlled by temperature (Marazzo and Valentin 2003). The biodiversity and presence of Cladocera in this study is similar to that of other studies in the southeastern Black Sea, Turkey (Ünal 2002; Özdemir and Ak 2012; Deniz 2013; Üstün et al. 2016, 2018). It was found in this study that the Cladocera abundance values detected in this study were higher than those of the Black Sea coastal areas of Trabzon (Özdemir and Ak 2012) and Sinop (except for 2008 and 2009) (Üstün et al. 2016, 2018) and were lower than those of Sinop (Ünal 2002; Üstün et al. 2018) and Samsun (Deniz 2013). Cladocera is one of the important nutritional zooplankton groups of coastal marine ecosystems and its presence is influenced by environmental factors (Isinibilir et al. 2008; Büyükateş and İnanmaz 2009; Terbiyik Kurt and Polat 2013; Alıçlı-Toklu and Sarıhan 2016). Cladocera is particularly dense in surface layers and abundant at a depth of up to 30 m. They need appropriate environmental conditions to successfully reproduce and spread near the surface. (Bosch and Taylor 1968). Coastal ecosystems are under the influence of terrestrial inputs (anthropogenic activities) and meteorological phenomena (e.g. rain) (Resmi et al. 2011). These factors affect the amount of inorganic nutrients and phytoplankton in the aquatic environment and many other physiochemical properties, which may have an impact on the distribution and abundance of Cladocera. This may be one of the reasons for the variable population of Cladocera in different coastal regions with different topographical and hydrographical properties.

The Chaetognatha *Parasagitta setosa* forms a large portion of the mesozooplankton assemblage in terms of biomass. Large or adult individuals have a higher distribution density in open seas, and small or young individuals have been observed in coastal waters (Ünal 2002). The breeding period of *P. setosa* is from June to November in the southern Black Sea (Besiktepe and Unsal 2000; Ünal 2002). In this study, the size of Chaetognatha varied from 0.5–1 mm to 12–13 mm. Individuals of Chaetognatha with a size between 1 and 2 mm and 4–5 mm fractions were found to be more abundant. The maximum contribution of size fractions between 1 and 2 mm and 4–5 mm was recorded in July and October 2013. The high abundance and biomass in July and October 2013 comprised young individuals.

Meroplankton, which consists of larvae of benthic organisms that live temporarily in pelagic environments, are an important part of the coastal marine environment in the Black Sea (Öztürk 2015; Yıldız and Feyzioğlu 2016). In the present study, 12 meroplankton groups were detected of which Bivalvia larvae constituted the dominant group. The highest abundance and biomass values of Bivalvia larvae were detected in July 2013. Şahin-Kurt et al. (2017) conducted a survey in the same region and during the same sampling period and determined that the Bivalvia *Chamelea gallina* peaked during the spring. Dalgic et al. (2009) reported that gametogenesis of this species begins in May off the Turkish coasts of the Black Sea and spawning takes place in June and July. One of the reasons for obtaining the high Bivalvia larvae abundance and biomass values, which started to increase in May 2013 and reached their maximum values in July 2013, may be due to *C. gallina*, whose reproductive period coincides with the sampling period.

Noctiluca scintillans, a heterotrophic dinoflagellate species, feeds on a wide variety of foods ranging from phytoplankton and zooplankton larvae and eggs to organic detritus and bacteria (Mikaelyan et al. 2014). Competing with many other zooplankton species for the same food sources, *N. scintillans* may significantly affect the zooplankton abundance in the areas where it is present (Elbrächter and Qi 1998; Yılmaz et al. 2005; Aytan and Şentürk 2018). In the present study, a negative correlation was found between the abundances of *N. scintillans* and Cladocera and Copepoda species, which are important nutritional components of mesozooplankton.

Conclusion

The present study is a part of a research program conducted to determine the biological diversity in the İğneada (Turkey) and Rezova (Bulgaria) regions, the area of which has been promoted as a cross-border marine protected area (MPA) within the MISIS project (**M**SFD Guiding **I**mprovements in the Black **S**ea **I**ntegrated Monitoring System) (MISIS Project 2015) to be funded by the European Union. The findings of this study provide the first data on mesozooplankton species composition (especially Copepoda and Cladocera), abundance and biomass in the Black Sea off the coast of İğneada. The study found that the mesozooplankton assemblage structure is driven by physical conditions (such as temperature and salinity). To be able to understand the assemblage structure of mesozooplankton in the region in more detail and to monitor the effect of new species such as *Oithona davisae* on the ecosystem, it is necessary to fully study the open sea, as well as, the coastal regions, and most importantly, to ensure the continuity of studies through ecosystem monitoring.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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