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Soft-bottom crustacean fauna from the Turkish coast of the Black and Marmara seas with new records

by

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Abstract

It is becoming increasingly important to monitor zoobenthic biodiversity in seas that are under industrial and anthropogenic pollution pressure, such as the Black Sea and the Marmara Sea. This study covers crustacean species in the Turkish waters of the Black Sea and the Marmara Sea, both of which are closed systems. Sampling was carried out in July–August 2019 and yielded 32 crustacean species from the Black Sea and 77 species from the Marmara Sea. In the Marmara Sea, two species [*Kupellonura mediterranea* and *Leucon* (*Macrauloleucon*) *siphonatus*] represent new records for the Turkish waters, and 12 species [*Cirolana cranchii*, *Cumella* (*Cumella*) *pygmaea*, *Cyathura carinata*, *Cymodoce truncata*, *Eurydice pulchra*, *Gammaropsis sophiae*, *Harpinia truncata*, *Iphinoe serrata*, *Iphinoe trispinosa*, *Liocarcinus pusillus*, *Nebalia strausi* and *Synchelidium maculatum*] are new to the Marmara Sea. The following species: *Gammaropsis palmata*, *Pontocrates arenarius*, and *Synchelidium haplocheles* are new records for the Black Sea. The order Amphipoda dominated in both seas in terms of the number of species and the number of individuals.

Key words: Crustacea, new records, Black Sea, Marmara Sea, species diversity, ecology

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1. Introduction

Turkey is surrounded by the Black Sea, the Aegean Sea, the Mediterranean Sea and the inland sea called the Marmara Sea. Although the Black Sea is very extensive compared to the Marmara Sea, it is a closed system fed by rivers (Tuğrul 2017). The sea, which for a long time was a lake connected to the Caspian Sea, is connected with the Mediterranean Sea through the Marmara Sea and the Istanbul Strait, also known as the Bosphorus (Beşiktepe et al. 1994; Zaitsev & Mamaev 1997). The Istanbul and Çanakkale (Dardanelles) straits, which are the narrowest straits in Europe, form the Turkish Straits System together with the Marmara Sea (Özsoy 2016). The Marmara Sea connects the Black Sea with the Mediterranean Sea and has a two-layer water system formed by waters originating in each of these seas. The upper layer consists of low-salinity Black Sea waters and the lower layer consists of high-salinity Mediterranean waters (Yüce, Türker 1991). While the density stratification between the layers prevents oxygen from reaching the substrate, particles of biogenic origin at the seabed increase oxygen consumption (Beşiktepe et al. 2000). While the saline Mediterranean waters are transported to the Black Sea through the Istanbul Strait, the salinity of surface waters drops due to substantial freshwater inflows from rivers such as the Danube, the Dniester, and the Dnieper. As a result of vertical stratification and high-rate transport of organic matter, the bottom layer is anoxic and contains high levels of sulfur (Tezcan et al. 2017). The Black Sea, whose coastlines are located in six countries, is characterized by high eutrophication levels due to transport from both rivers and anthropogenic effects (Bakan & Büyükgüngör 2000). Another common feature between these two closed seas is their unique fauna and flora. The fauna of the Black Sea, in particular, differs significantly from that of other seas due to its anoxic nature and high biomass production, as well as its low biodiversity compared to the Mediterranean Sea (Alexandrov & Zaitsev 1998; Bat et al. 2011). At present, both seas are under intense pressure from pollution. While rivers are the main source of pollution in the Black Sea, the Marmara Sea is heavily affected by nearby industrial facilities, anthropogenic factors and marine traffic (Aksu et al. 2016; Balkıs et al. 2016; Ünlü 2016; Frid & Caswell 2017). For this reason, it is critical to regularly monitor biodiversity, which is greatly affected by environmental factors. Arthropods in particular occupy an important place in the benthic fauna of the Black Sea in terms of the number of species (Sezgin & Kurt-Şahin 2017). Crustacea, which constitute the majority of Arthropoda not only in the Black Sea but in all marine ecosystems, are a very large group of animals that are widespread in marine habitats, but also in freshwater (Sampaio et al. 2016).

Research on Crustacea in the Black Sea goes back to Holthuis (1961) and Kocataş (1981, 1982), followed by Mutlu & Ünsal (1991–1992, 1992), Mutlu et al. (1992), Öztürk (1999), Bat et al. (2000), Sezgin et al. (2001), Kocataş & Katağan (2003), Bilgin & Çelik (2004), Gönlügür-Demirci & Katağan (2004), Bilgin & Gönlügür-Demirci (2005), Gönlügür-Demirci (2006), Kırkım et al. (2006), Sezgin & Katağan (2007), Bilgin et al. (2007), Karaçuha et al. (2009), Ateş et al. (2010), Sezgin et al. (2010a,b), Balkıs et al. (2012), Kırkım et al. (2014), Kurt-Şahin et al. (2017). A number of researchers have also tried to explore the crustacean fauna of the Marmara Sea, including Sowinsky (1897), Demir (1952), Holthuis (1961), Caspers (1968), Băcescu (1982), Balkıs (1992), Kocataş and Katağan (1993), Topaloğlu (1993; 2014), Balkıs (1994), Balkıs (1998–99a,b), Uysal et al. (2002), Balkıs et al. (2002), Yurdabak (2004), Kalkan et al. (2006), Ritt et al. (2010), Bakır et al. (2011), Aslan-Cihangir & Panucci-Papadopolou (2011), Bakır (2012), Mülayim et al. (2015a,b), Bakır et al. (2016), Ayfer et al. (2017) and Bakır & Ateş (2018).

As demonstrated above, crustaceans in the Black Sea and the Marmara Sea have already been the subject of many studies. Most of these studies targeted limited areas in these seas to study crustacean species. There are no studies in the literature that cover crustaceans from the Black Sea and the Marmara Sea together. This study presents detailed and up-to-date information on the soft-bottom crustacean fauna of this large and important region based on samples collected at different locations representing the Turkish waters of the Black Sea and the Marmara Sea. This provides insight into similarities and differences in the crustacean fauna of both seas. Overall, I have updated the list of crustacean species with new records for these areas and provided information on their habitats.

2. Materials and methods

Sampling for the study was conducted within the scope of the "Integrated Marine Pollution Monitoring 2017–2019 Program" coordinated by TÜBİTAK – Marmara Research Center of the Environment and Cleaner Production Institute with the support of the Ministry of Environment and Urbanization of the Turkish Republic. Sampling was carried out in the Marmara Sea between 24 July and 1 August 2019 and in the Black Sea between 4 and 16 July 2019 from the TUBİTAK Marmara Research Vessel.

Sampling was carried out at 27 sites at a depth ranging from 10 to 87 m in the Marmara Sea and the Istanbul Strait, and at 20 sites at a depth of 8.5–45 m in the area between İğneada and Hopa in the Black Sea (Fig. 1). Three replicate samples were collected using a Van Veen Grab sampler in an area of 0.1 m^2. Information about the sites is provided in detail in Table 1. Sediment samples were sieved through a 0.5 mm mesh sieve and fixed with 4% formaldehyde solution. They were examined under a Leica M205C Stereomicroscope to determine the number of species and individuals.

Species were identified using a number of references (Barnard 1925; Monod 1926; Bouvier 1940; Zariquiey-Alvarez 1946; 1968; Tattersall & Tattersall 1951; Bacescu 1954; Holthuis 1956; Naylor 1972; Jones 1976; Wägele 1981; Bacescu 1982; 1988; Bellan-Santini et al. 1982; 1989; 1993; 1998; Holdich & Jones 1983; Holthuis 1987; Watling 1991; Koçak et al. 2007; Curatolo et al. 2013). The nomenclature follows WoRMS (2020).

The frequency index (*Fi*) of Soyer (1970) was used to determine the frequency of crustacean species in the study area. According to the calculated *Fi* values, the results were categorized into three groups: "constant" (*Fi* 50%), "common" (50% > *Fi* ≥ 25%) and "rare" (*Fi* < 25%). The dominance index (*Di*) was used to determine the dominance of crustacean species in the study area (Bellan-Santini 1969). The evenness index (*J'*) and the Shannon–Wiener index were used to determine the diversity of crustacean species (Shannon & Weaver 1963; Pielou 1966). Multidimensional scaling (MDS) methods were used to analyze the Bray–Curtis similarity index and the regional distribution model to determine similarity between the sampling locations. To this end, log (x + 1) transformation was applied to the raw data. The percentage contribution of each species to the similarities and differences derived from the stack analysis was determined using the SIMPER analysis. Primer 6 software (Clarke & Warwick 2001) was used for the analysis.

3. Results

A total of 32 crustacean species were found in the Black Sea during the study (Table 2). The order Amphipoda (50%) was represented by the largest number of species and was followed by Decapoda (19%; Fig. 2). The least frequent order was Mysida, which was represented by only one species – *Gastrosaccus sanctus* (Van Beneden, 1861). Three amphipods [*Gammaropsis palmata* (Stebbing & Robertson, 1891), *Pontocrates arenarius* (Bate 1858), and *Synchelidium haplocheles* (Grube, 1864)] of the identified species were reported for the first time from the Black Sea. Considering the values of the frequency index, only two species [*Ampelisca pseudospinimana* Bellan-Santini & Kaim-Malka, 1977 and *Perioculodes longimanus* (Spence Bate & Westwood, 1868)] are constant and six species [*Ampelisca diadema* (Costa, 1853), *Ampelisca pseudosarsi* Bellan-Santini & Kaim-Malka, 1977, *Iphinoe tenella* Sars, 1878, *Iphinoe trispinosa* (Goodsir, 1843), *Pseudocuma* (*Pseudocuma*) *longicorne* (Bate, 1858) and *Diogenes*

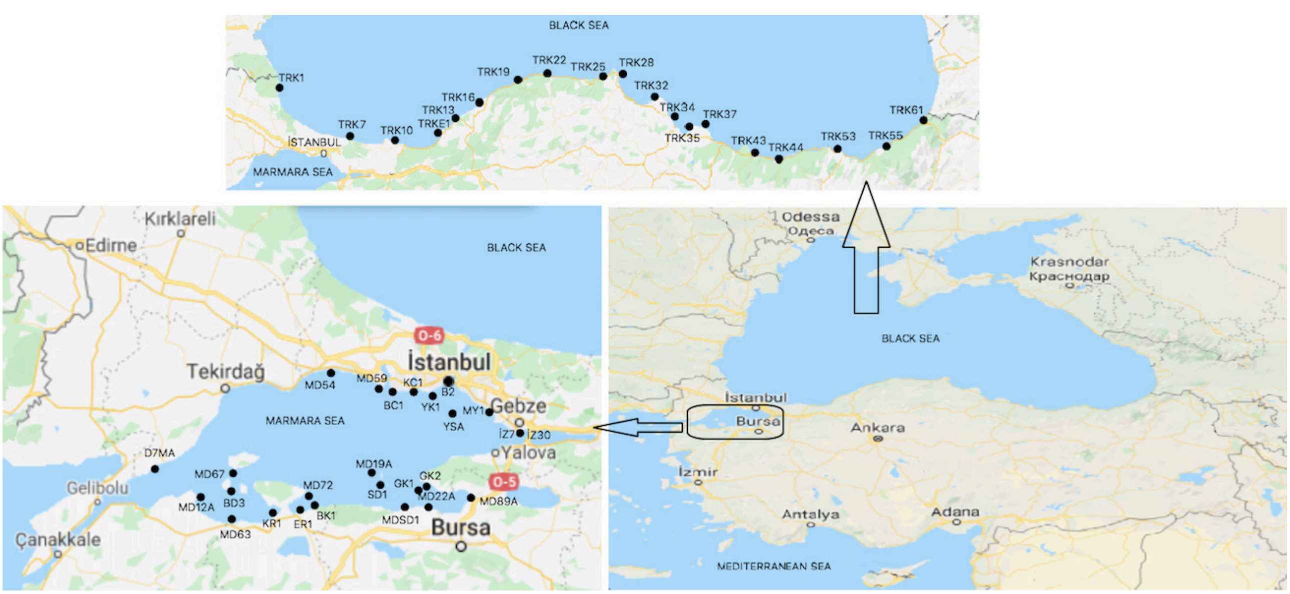

Figure 1

Map of the sampling sites

Table 1

Codes, coordinates, habitat structure, sampling dates and depth of the sampling locations in the Black Sea and the Marmara Sea

Site code	Site name	Date	Depth (m)	Coordinates		Substrate
				Latitude	Longitude	
THE BLACK SEA						
TRK1	İğneada and Danube River water	04.07.2019	20	41°52′12′′N	28°3′33′′E	shells and sand
TRK7	Şile	05.07.2019	22	41°11′30′′N	29°35′24′′E	mud
TRK10	Sakarya River	06.07.2019	21	41°8′45′′N	30°37′39′′E	mud
TRKE1	Karadeniz Ereğlisi	07.07.2019	14	41°16′28′′N	31°23′54′′E	shells and fine sand
TRK13	Zonguldak	07.07.2019	20	41°27′36′′N	31°46′24′′E	detrital black sandy mud
TRK16	Bartın	08.07.2019	22	41°35′32′′N	32°3′3′′E	phytodetritus
TRK19	Cide	08.07.2019	24	41°54′43′′N	32°55′32′′E	shells and mud
TRK22	İnebolu	09.07.2019	25	41°59′17′′N	33°47′2′′E	shells and detrital mud
TRK25	Sinop 2	09.07.2019	20	41°3′49′′N	34°55′4′′E	mud
TRK28	Sinop 1	10.07.2019	22	41°0′57′′N	35°9′28′′E	shells and coarse sand
TRK32	Kızılırmak	10.07.2019	24	41°44′44′′N	35°57′26′′E	mud
TRK34Y	Samsun	12.07.2019	20	41°19′1′′N	36°21′35′′E	mud with phytodetritus
TRK35	Samsun	11.07.2019	48	41°20′49′′N	36°23′23′′E	shells
TRK37	Yeşilırmak	13.07.2019	8.5	41°23′37′′N	36°39′9′′E	mud
TRK43	Ordu	14.07.2019	11.6	41°0′14′′N	37°53′36′′E	shells and sand
TRK44	Ordu	14.07.2019	48	41°1′14′′N	37°54′27′′E	phytodetritus clay
TRK46	Giresun	14.07.2019	20	40°55′21′′N	38°24′21′′E	mud
TRK53	Trabzon	15.07.2019	35	41°1′0′′N	39°43′42′′E	mud with phytodetritus and sand
TRK55	Rize	16.07.2019	25	41°2′ 7′′N	40°32′ 20′′E	shells and mud
TRK61	Hopa	16.07.2019	45	41°30′52′′N	41°30′50′′E	mud
THE MARMARA SEA						
İZ7	İzmit Bay	24.07.2019	65	40°45′54′′N	29°27′38′′E	mud, fine sand, shells
İZ30	İzmit Bay	24.07.2019	27	40°45′15′′ N	29°54′47′′E	clay, phytodetritus
MY1	Pendik	24.07.2019	38	40°52′4′′N	29°14′27′′E	mud and fine sand
YSA	Yassıada	23.07.2019	87	40°51′23′′N	28°59′12′′E	clay and fine sand
B2	İstanbul Strait	26.07.2019	30	41°1′ 46′′N	29°0′50′′E	mud and fine sand
YK1	Yenikapı shore	26.07.2019	15	40°56′26′′N	28°50′20′′E	coralline, mud, fine sand
KC1	Küçükçekmece shore	27.07.2019	20	40°58′12′′N	28°45′20′′E	clay, phytodetritus
BC1	Büyükçekmece shore	27.07.2019	51	40°56′51′′N	28°36′22′′E	clay, fine sand
MD54	Silivri shore	27.07.2019	31	41°3′26′′N	28°14′27′′E	clay, fine sand
MD59	Tekirdağ shore	28.07.2019	20	40°57′40′′N	28°31′29′′E	mud, fine sand
D7MA	Şarköy	28.07.2019	32	40°33′14′′N	27°1′27′′E	mud, fine sand, shells
BD3	Erdek Bay	28.07.2019	37	40°25′25′′N	27°22′37′′E	mud, fine sand, shells
MD12A	Erdek Bay	29.07.2019	44	40°25′17′′N	27°32′1′′E	mud, fine sand, shells
BK1	Bandırma	30.07.2019	35	40°22′12′′N	27°57′42′′E	mud, shells, phytodetritus
MD72	Bandırma	30.07.2019	44	40°24′27′′N	28°4′24′′E	mud, shells
MD19A	Bayramdere	31.07.2019	43	40°32′10′′N	28°25′24′′E	mud, fine sand
SD2	Susurluk Stream	31.07.2019	10	40°24′32′′N	28°31′11′′E	fine sand
MD89A	Gemlik Bay	1.08.2019	39	40°25′50′′N	29°8′17′′E	mud, phytodetritus
MD22A	Gemlik Bay	31.07.2019	35	40°22′51′′N	28°53′11′′E	mud, phytodetritus
GK2	Gemlik Bay	1.08.2019	39	40°29′42′′N	28°49′27′′E	mud, shells
MD24	Yalova Shore	1.08.2019	51	40°40′0′′N	29°14′52′′E	mud
GK1	Gemlik Bay	31.07.2019	64	40°27′13′′N	28°45′10′′E	mud
MDSD1	Mudanya	31.07.2019	27	40°23′13′′N	28°43′44′′E	clay, phytodetritus
ER1	Erdek Bay	29.07.2019	33	40°23′44′′N	28°2′15′′E	mud, fine sand, shells
KR1	Kurşunlu shore	30.07.2019	47	40°20′38′′N	27°48′7′′E	mud, fine sand
MD67	Erdek Bay	29.07.2019	60	40°32′55′′N	27°34′36′′E	mud, fine sand, shells
MD63	Denizkent-Erdek Bay	29.07.2019	15	40°19′5′′N	27°32′34′′E	mud, phytodetritus

Table 2

Crustacean species found in the Black Sea; Frequency (*Fi*) and Dominance Index (*Di*) values

	TRK 1	TRK 7	TRK 10	TRK E1	TRK 13	TRK 16	TRK 19	TRK 22	TRK 25	TRK 28	TRK 32	TRK 34Y	TRK 35	TRK 37	TRK 43	TRK 44	TRK 46	TRK 53	TRK 55	TRK 61	*Fi* %	*Di* %
MYSIDA																						
Gastrosaccus sanctus (Van Beneden, 1861)			3					3													10	0.2
AMPHIPODA																						
Ampelisca diadema (Costa, 1853)							17	7	73		3				7	30		13	20		40	6.3
Ampelisca pseudosarsi Bellan-Santini & Kaim-Malka, 1977		3		30	10		3	70	47	3											35	6.1
Ampelisca pseudospinimana Bellan-Santini & Kaim-Malka, 1977	27	57			7		3				3	30	7		43	7	7		107	7	60	11.2
Ampelisca sp.		7					20		90			3			3	3			10		35	5
Amphipoda (sp.)	3										10										10	0.5
Apocorophium acutum (Chevreux, 1908)											3				107				10		15	4.4
Bathyporeia guilliamsoniana (Spence Bate, 1857)		23							120												10	5.3
Dexamine spiniventris (Costa, 1853)										3	3										10	0.2
Ericthonius brasiliensis (Dana, 1853)															50						5	1.8
**Gammaropsis palmata* (Stebbing & Robertson, 1891)							3		20												10	0.8
Medicorophium runcicorne (Della Valle, 1893)							3		7		10					7					20	1
Medicorophium sp.							7	3		3											15	0.5
Megaluropus massiliensis Ledoyer, 1976		7							20												10	1
Microdeutopus sp.										13											5	0.5
Microdeutopus versiculatus (Spence Bate, 1857)	57						40			7			3								20	3.9
Perioculodes longimanus (Spence Bate & Westwood, 1868)		33		7	3		17	7	27	13	3				7	40	3		10	3	65	6.4
Perioculodes sp.		3					3														10	0.2
Phtisica marina Slabber, 1769							3			3			3								15	0.3
**Pontocrates arenarius* (Spence Bate, 1858)																		3			5	0.1
**Synchelidium haplocheles* (Grube, 1864)					7		7	3		10											20	1
Synchelidium maculatum Stebbing, 1906							3														5	0.1
ISOPODA																						
Eurydice pulchra Leach, 1815	7	7	70		3																20	3
Isopoda (sp.)			3																		5	0.1
Paragnathia formica (Hesse, 1864)										7											5	0.1
TANAIDACEA																						
Apseudopsis acutifrons (Sars, 1882)	13							13					17								15	1.6
Apseudopsis latreillii (Milne Edwards, 1828)							3	7	7			3			7				13		30	1.5
CUMACEA																						
Cumacea (sp.)							3														5	0.1
Iphinoe serrata Norman, 1867															3						5	0.1
Iphinoe sp.										7		3	23			3			3	3	30	1.5
Iphinoe tenella Sars, 1878							7			3						7	57	283	13	27	35	14.6
Iphinoe trispinosa (Goodsir, 1843)		7					3	10		3		23	67		3	50			10		45	6.5
Eudorella truncatula (Bate, 1856)													7			10				17	15	1.3
Pseudocuma (Pseudocuma) longicorne (Bate, 1858)		3		17			3	3	73						70		3		10		40	6.7
DECAPODA																						
Athanas nitescens (Leach, 1813)										10											5	0.4
Brachynotus sexdentatus (Risso, 1827)			10									3									10	0.5
Decapoda (sp.)	3											3									10	0.2
Gebiidea (sp.)															10	3					10	0.5
Diogenes pugilator (Roux, 1829)		3	3		3			3		3					3			37	10		40	2.4
Liocarcinus depurator (Linnaeus, 1758)	7																				5	0.3
Pilumnus hirtellus (Linnaeus, 1761)										3											5	0.1
Upogebia pusilla (Petagna, 1792)	23					3						7									15	1.2
Upogebia sp.																			3		5	0.1

*New record for the Black Sea

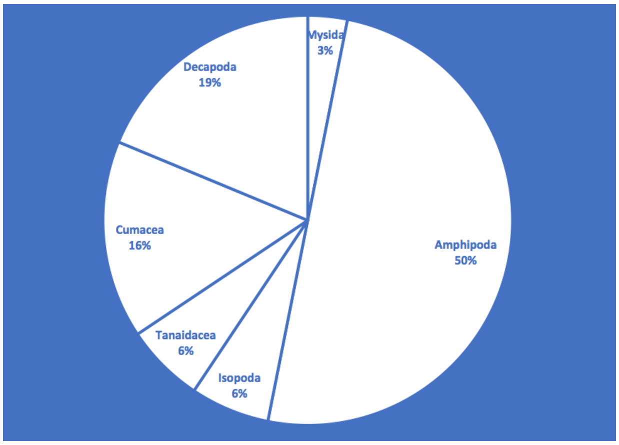

Figure 2

Distribution of species per order in the Black Sea

pugilator (Roux, 1829)] are common. The remaining species can be described as rare. The species with the highest dominance indices were *I. tenella* (14.6%) and *A. pseudospinimana* (11.2%; Table 2). The highest similarity (68%) between the locations sampled in the Black Sea was found between the TRK46 site in Giresun and the TRK61 site in Hopa. *I. tenella*, *A. pseudospinimana* and *P. longimanus* contributed most to this similarity. The second highest similarity (62.2%) was observed between TRK43 in Ordu and TRK55 in Rize. *A. pseudospinimana*, *A. acutum* and *Pseudocuma* (*Pseudocuma*) *longicorne* (Bate, 1858) contributed most to the similarity (Fig. 3).

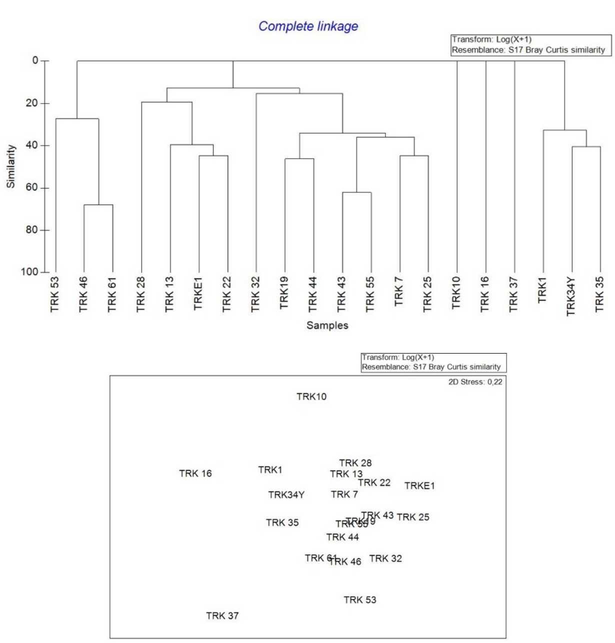

Figure 3

Similarity between the Black Sea sites

A total of 77 crustacean species were identified in the Marmara Sea and two of them [*Kupellonura mediterranea* Barnard, 1925, *Leucon* (*Macrauloleucon*) *siphonatus* Calman, 1905] represent new records for the Turkish Seas, 12 species [*Cirolana cranchii* Leach, 1818, *Cumella* (*Cumella*) *pygmaea* G.O. Sars, 1865, *Cyathura carinata* (Krøyer, 1847), *Cymodoce truncata* Leach, 1814, *Eurydice pulchra* Leach, 1815, *Gammaropsis sophiae* (Boeck, 1861), *Harpinia truncata* Sars, 1891, *Iphinoe serrata* Norman, 1867, *Iphinoe trispinosa* (Goodsir, 1843), *Liocarcinus pusillus* (Leach, 1816), *Nebalia strausi* Risso, 1826 and *Synchelidium maculatum* Stebbing, 1906] are reported for the first time from the Marmara Sea (Table 3). *K. mediterranea*, which is a new record for the Turkish Seas, is an isopod species found at three sites in Erdek Bay during the study. Of these sites, BD3 was 37 m deep, MD12A was 44 m deep and MD67 was 60 m deep. The substrate at all three sites was mud, fine sand and shells. *Leucon* (*Macrauloleucon*) *siphonatus*, belonging to Cumacea, was found in Erdek Bay at a depth of 60 m. The substrate at this site was also mud, fine sand and shells. As in the Black Sea, most species (63%) from the Marmara Sea belonged to the order Amphipoda, followed by Decapoda (14%). Species from the Mysida order were not found (Fig. 4).

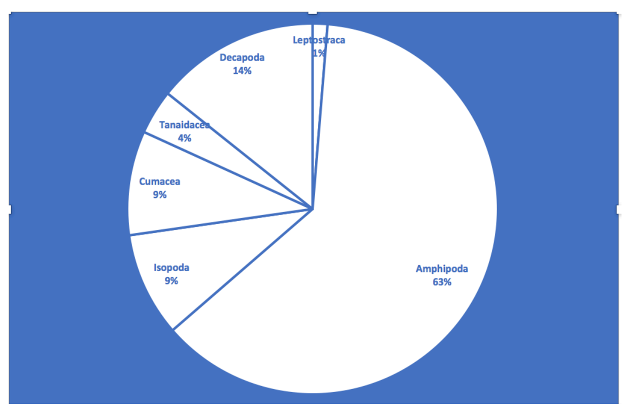

Figure 4

Distribution of species per order in the Marmara Sea

Only two species [*A. diadema* (52%) and *I. trispinosa* (67%)] were constant in the Marmara Sea, while *Ampelisca planierensis* Bellan-Santini & Kaim-Malka, 1977, *A. pseudospinimana*, *G. palmata*, *P. longimanus*, *Phtisica marina* Slabber, 1769 and *Apseudopsis acutifrons* (Sars, 1882) were common, the remaining species were categorized as rare. The species with the highest dominance indices were *Apocorophium acutum* (Chevreux, 1908) – 27.5% and *Microdeutopus gryllotalpa* A. Costa, 1853 – 14.1%.

The sites with the highest similarity (66.67%) in the Marmara Sea were YSA sites in Yassıada and GK1 sites in Gemlik Bay. It is seen that station groups BC1 on Buyukcekmece shore, GK2 on Gemlik Bay and KR1 on Kursunlu shore with a similarity index of 58.28% take the second place (Fig. 5). *Diastyloides bosphorica* (Băcescu, 1982) contributed greatly to the similarity of the first group, and *A. diadema*, *A. planierensis* and *D. bosphorica* contributed most to the similarity of the second group.

The lowest value of the diversity index (*H'*) in the Black Sea was found for TRK16 (*H'* = 0) in Bartın, where three individuals belonging to one species were found and TRK37 (*H'* = 0) Yeşilırmak (Table 4, Fig. 6). The second lowest scores were determined for TRK53 in Trabzon (*H'* = 0.8), TRK46 in Giresun (*H'* = 1), and TRK10 (*H'* = 1.1) in the Sakarya River. The highest *H'* value was obtained for site TRK28 in Sinop 1 (3.7) and site TRK19 in Cide (3.5). In the Marmara Sea, *H'* values were 0 at four sites (MD89A, YSA and İZ30, KC1), which are located in Gemlik Bay, Yassıada, Izmit Bay and on the Küçükçekmece shore (Table 4, Fig. 7). The second lowest value (*H'* = 0.9) was determined for MD22A and GK1 (*H'* = 1), also located in Gemlik Bay, and BK1 in Bandırma Bay. The highest value (*H'* = 3.8) was determined for YK1 in Yenikapı, D7MA (*H'* = 3.4) in Şarköy and MD63 (*H'* = 3.2) in Denizkent-Erdek Bay.

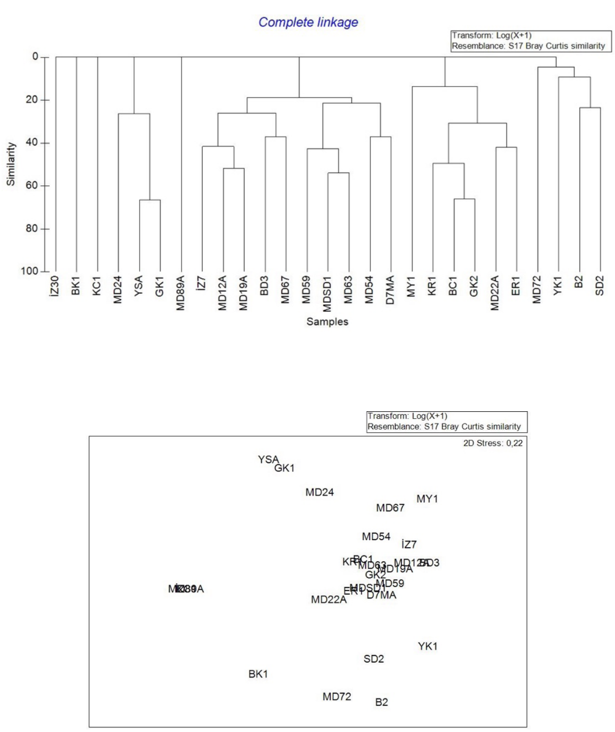

Figure 5

Similarity between the Marmara Sea sites

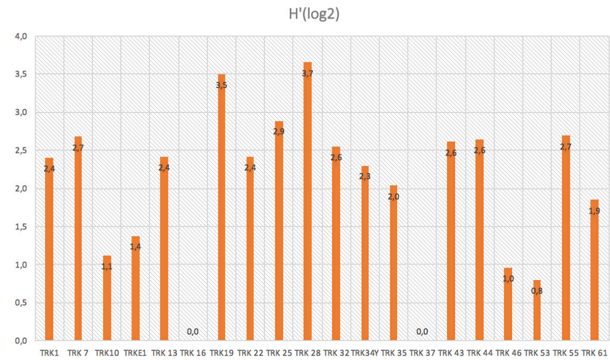

Figure 6

H´ values for the Black Sea sites

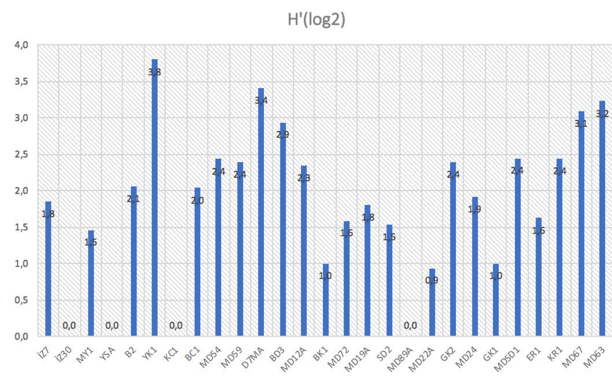

Figure 7

H´ values for the Marmara Sea sites

4. Discussion

Biodiversity in the Black Sea is quite low compared to other seas (Gönlügür et al. 2004; Bat et al. 2011). Our study corroborates previous findings regarding the difference in biodiversity between these two seas by identifying 77 crustacean species in the Marmara Sea and only 32 species in the Black Sea. Bakır et al. (2014) reported the presence of 172 benthic crustacean species in the Black Sea, but approximately 30 species were found only in soft-bottom benthos (Kırkım et al. 2006; Sezgin et al. 2010b). Kırkım et al. (2006) observed the dominance of *Pseudocuma longicorne*, *Iphinoe elisae*, *Iphinoe tenella*, *Ampelisca diadema*, *Bathyporeia guilliamsoniana* and *Perioculodes longimanus longimanus*. Similarly, *P. longimanus*, *P. longicorne*, *I. tenella*, *A. diadema* were found to be common species in this study, along with *A. pseudospinimana*, *A. pseudosarsi*, *I. trisipinosa* and *D. pugilator*. Other species commonly identified by the above-mentioned researchers were found in this study, but were classified into the category of rare species. The dominance of *I. tenella* from Cumacea was

Table 3

Crustacean species identified in the Marmara Sea; Frequency (*Fi*) and Dominance Index (*Di*) values

	İ Z 7	İ Z 30	M Y 1	Y S A	B 2	Y K 1	K C 1	B C 1	M D 54	M D 59	D 7 M A	B D 3	M D 12 A	B K 1	M D 72	M D 19 A	S D 2	M D 89 A	M D 22 A	G K 2	M D 24	G K 1	M D S D 1	E R 1	K R 1	M D 67	M D 63	*Fi* %	*Di* %
LEPTOSTRACA																													
Nebalia strausi Risso, 1826						10					7																	7	0.06
AMPHIPODA																													
Ampelisca diadema (Costa, 1853)					3	7		117		20	20		13		3	63	27		53	33			243		73		43	52	2.49
Ampelisca gibba Sars, 1883												7														40		7	0.16
Ampelisca planierensis Bellan-Santini & Kaim-Malka, 1977			7					203			40								807	157			63	317	13		47	33	5.74
Ampelisca pseudospinimana Bellan-Santini & Kaim-Malka, 1977	13								27	73	7	30	77			43				113	3		850			30	130	44	4.85
Ampelisca sp.	100		3			3		107	37	17	100	40	83			93				113			113	50	43	50	33	59	3.42
Ampelisca spinipes Boeck, 1861	40																											4	0.14
Ampelisca tenuicornis Lilljeborg, 1855									50		10						7				7							15	0.26
Ampelisca typica (Spence Bate, 1856)											10																	4	0.03
Ampithoe ramondi Audouin, 1826						3																						4	0.01
Aora gracilis (Spence Bate, 1857)						3																						4	0.01
Apherusa chiereghinii Giordani- Soika, 1949																3												4	0.01
Apocorophium acutum (Chevreux, 1908)					7903							3																4	27.45
Apolochus neapolitanus (Della Valle, 1893)																	7											4	0.02
Autone sp.													3															4	0.01
Autonoe karamani (Myers, 1976)													10															4	0.03
Caprella acanthifera Leach, 1814																							7					4	0.02
Caprella rapax Mayer, 1890						3																						4	0.01
Carangoliopsis spinulosa Ledoyer, 1970												7																4	0.02
Centraloecetes dellavallei (Stebbing, 1899)						7											27											7	0.12
Corophium sp.									3										3									7	0.02
Gammarella fucicola (Leach, 1814)					520																							4	1.81
Gammaropsis palmata (Stebbing & Robertson, 1891)					3			23			3					10							57	17			7	26	0.42
**Gammaropsis sophiae* (Boeck, 1861)																					3			3		13		11	0.07
Gitana sarsi Boeck, 1871	3					3		3												7								15	0.06
Harpinia crenulata (Boeck, 1871)						17																						4	0.06
Harpinia dellavallei Chevreux, 1910						3					13																	7	0.06
**Harpinia truncata* Sars, 1891												10													10			7	0.07
Hippomedon massiliensis Bellan-Santini, 1965																	3											4	0.01
Jassa marmorata Holmes, 1905					230																							4	0.80
Leptocheirus mariae Karaman, 1973												10			3					3			310				17	19	1.19
Leucothoe incisa Robertson, 1892																											7	4	0.02
Leucothoe lilljeborgi Boeck, 1861	7												10				3											11	0.07
Maera grossimana (Montagu, 1808)					53																							4	0.18
Maera sp.					3																							4	0.01
Medicorophium rotundirostre (Stephensen, 1915)						3			3		20																17	15	0.15
Medicorophium runcicorne (Della Valle, 1893)						3																	3				3	11	0.03
Medicorophium sp.						3				3	3																	11	0.03
Megamphopus cornutus Norman, 1869										33																		4	0.11
Melita palmata (Montagu, 1804)					40																							4	0.14
Microdeutopus algicola Della Valle, 1893					233												13											7	0.85
Microdeutopus gryllotalpa A. Costa, 1853					4070																							4	14.13
Microdeutopus sp.						7																						4	0.02

Microdeutopus versiculatus (Spence Bate, 1857)						27				17													30					11	0.26
Paraphoxus oculatus (G. O. Sars, 1879)																										23		4	0.08
Parvipalpus linea Mayer, 1890																							23	3				7	0.09
Perioculodes longimanus (Spence Bate & Westwood, 1868)									3	20							83		30				40	7	3		3	30	0.66
Photis longicaudata (Spence Bate & Westwood, 1862)												3	10															7	0.05
Phtisica marina Slabber, 1769					963	73					3	3					17			13			10	13				30	3.80
Pontocrates arenarius (Spence Bate, 1858)																											10	4	0.03
Pseudoprotella phasma (Montagu, 1804)													3													3		7	0.02
Stenothoe monoculoides (Montagu, 1813)						17																						4	0.06
**Synchelidium maculatum* Stebbing, 1906																							7					4	0.02
Tryphosa nana (Krøyer, 1846)						17				7	20																	7	0.15
Westwoodilla caecula (Spence Bate, 1857)												7																4	0.02
ISOPODA																													
**Cirolana cranchii* Leach, 1818																										3		4	0.01
**Cyathura carinata* (Krøyer, 1847)																										3		4	0.01
**Cymodoce truncata* Leach, 1814						3																						4	0.01
**Eurydice pulchra* Leach, 1815																	793											4	2.75
Gnathia dentata (Sars G.O., 1872)											3																	4	0.01
***Kupellonura mediterranea* Barnard, 1925												3	3													3		11	0.03
Paragnathia formica (Hesse, 1864)						3							3															7	0.02
TANAIDACEA																													
Apseudopsis acutifrons (Sars, 1882)																											33	4	0.11
Apseudopsis latreillii (Milne Edwards, 1828)					6653				3	3							67			3								19	23.36
Chondrochelia savignyi (Kroyer, 1842)						60																			3			7	0.22
CUMACEA																													
Cumacea (sp.)	3																											4	0.01
**Cumella* (*Cumella*) *pygmaea* G.O. Sars, 1865						37																						4	0.13
Diastyloides bosphorica (Băcescu, 1982)				3				27		3										27	17	3	3		43		40	33	0.58
Diastyloides serratus (Sars G.O., 1865)	10													17					20				3	33	10			22	0.32
Diastyloides sp.									7																			4	0.02
Eudorella truncatula (Bate, 1856)											3																	4	0.01
**Iphinoe serrata* Norman, 1867																			13				3			3		11	0.07
Iphinoe sp.										30																		4	0.10
**Iphinoe trispinosa* (Goodsir, 1843)										247	7												7				67	11	1.14
***Leucon* (*Macrauloleucon*) *siphonatus* Calman, 1905																										1		4	0.003
Leucon sp.																										3		4	0.01
DECAPODA																													
Anomura *sp.*																	7											4	0.02
Callianassa subterranea (Montagu, 1808)																										3		4	0.01
Decapoda (sp.)			3					3					3													3	3	19	0.05
Diogenes pugilator (Roux, 1829)																	3											4	0.01
Gebiidea (sp.)											13	3																7	0.06
Liocarcinus depurator (Linnaeus, 1758)					3										3		3			3								15	0.04
Liocarcinus marmoreus (Leach, 1814)						3																						4	0.01
Liocarcinus navigator (Herbst, 1794)					13																							4	0.05
**Liocarcinus pusillus* (Leach, 1816)					3																							4	0.01
Liocarcinus sp.																							3					4	0.01
Pagurus cuanensis Bell, 1845						3																						4	0.01
Processa edulis (Risso, 1816)																								10				4	0.03
Processa macrophthalma Nouvel & Holthuis, 1957									3		7			17														11	0.09
Processa sp.									3		7								7		3	3			3	3		26	0.10
Upogebia pusilla (Petagna, 1792)						10																						4	0.03
Upogebia sp.						3																						4	0.01
Xantho poressa (Olivi, 1792)						3																						4	0.01

*New record for the Marmara Sea; ** New record for the Turkish seas

Table 4

Shannon–Wiener diversity index (*H'*) values

THE BLACK SEA						
Site code	Site name	S	N	d	*J'*	*H'*(log2)
TRK1	İğneada and Danube River water	8	140	1.4	0.8	2.4
TRK7	Şile	11	153	2	0.8	2.7
TRK10	Sakarya River	5	89	0.9	0.5	1.1
TRKE1	Karadeniz Ereğlisi	3	54	0.5	0.9	1.4
TRK13	Zonguldak	6	33	1.4	0.9	2.4
TR16	Bartın	1	3	0	0	0
TRK19	Cide	18	148	3.4	0.8	3.5
TRK22	İnebolu	11	129	2.1	0.7	2.4
TRK25	Sinop 2	10	484	1.5	0.9	2.9
TRK28	Sinop 1	15	91	3.1	0.9	3.7
TRK32	Kızılırmak	7	35	1.7	0.9	2.6
TRK34Y	Samsun	8	75	1.6	0.8	2.3
TRK35	Samsun	7	127	1.2	0.7	2
TRK37	Yeşilırmak	0	0	0	0	0
TRK43	Ordu	12	313	1.9	0.7	2.6
TRK44	Ordu	10	160	1.8	0.8	2.6
TRK46	Giresun	4	70	0.7	0.5	1
TRK53	Trabzon	4	336	0.5	0.4	0.8
TRK55	Rize	12	219	2	0.8	2.7
TRK61	Hopa	5	57	1	0.8	1.9
THE MARMARA SEA						
İZ7	İzmit Bay	7	176	1.16	0.66	1.8
İZ30	İzmit Bay	0	0	0	0	0
MY1	Pendik	3	13	0.78	0.92	1.5
YSA	Yassıada	1	3	0	0	0
B2	İstanbul Strait	15	20693	1.41	0.53	2.1
YK1	Yenikapı Shore	27	334	4.47	0.80	3.8
KC1	Küçükçekmece shore	0	0	0	0	0
BC1	Büyükçekmece shore	7	483	0.97	0.73	2
MD54	Silivri shore	10	139	1.82	0.73	2.4
MD59	Tekirdağ shore	12	473	1.79	0.67	2.4
D7MA	Şarköy	19	296	3.16	0.80	3.4
BD3	Erdek Bay	12	126	2.27	0.82	2.9
MD12A	Erdek Bay	11	218	1.86	0.68	2.3
BK1	Bandırma	2	34	0.28	1	1
MD72	Bandırma	3	9	0.91	1	1.6
MD19A	Bayramdere	5	212	0.75	0.78	1.8
SD2	Susurluk Stream	14	1060	1.87	0.40	1.5
MD89A	Gemlik Bay	0	0	0	0	0
MD22A	Gemlik Bay	8	943	1.02	0.31	0.9
GK2	Gemlik Bay	10	472	1.46	0.72	2.4
MD24	Yalova shore	5	33	1.14	0.82	1.9
GK1	Gemlik Bay	2	6	0.56	1	1
MDSD1	Mudanya	18	1775	2.27	0.59	2.4
ER1	Erdek Bay	9	453	1.31	0.51	1.6
KR1	Kurşunlu shore	9	201	1.51	0.77	2.4
MD67	Erdek Bay	16	191	2.86	0.77	3.1
MD63	Denizkent-Erdek Bay	15	460	2.28	0.83	3.2

observed in both studies, followed by the *Ampelisca* genus. The results obtained by Sezgin et al. (2010b) were quite similar to those obtained in this study. The study by Sezgin et al. (2010b) was conducted on the southern coast of the Black Sea, with 30 crustacean species identified. Their findings showed the following distribution of species per order: Amphipoda (70%), Cumacea (13%), Decapoda (10%) and Tanaidacea (7%). In this study, the distribution of species was as follows: Amphipoda (50%), Decapoda (19%), Cumacea (16%), Tanaidacea (6%), Isopoda (6%) and Mysidacea (3%). As evidenced, species of Amphipoda, Cumacea and Decapoda occupy an important place in the benthic crustacean fauna of the Black Sea. *Pseudocuma longicorne* (37%) occurred with the highest frequency index according to the Kırkım et al. (2006) and Sezgin et al. (2010b), followed by *Iphinoe tenella*, *Ampelisca diadema*, *Iphinoe elisae* and *Perioculodes longimanus*. The dominant species in that study were: *I. elisae* (25%), *I. tenella* (17%), *A. diadema* (16%), *P. longicorne* (11%) and *Bathyporeia guilliamsoniana* (6%). In this study, *I. tenella* (14.6%), *A. pseudospinimana* (11.2%) and *Pseudocuma longicorne* (6.7%) were dominant. Mutlu et al. (1992), like other researchers, also stated that amphipods have an important place in the diversity of the crustacean fauna in the Turkish waters of the Black Sea. They also mentioned the dominance of *Ampelisca diadema*, *Phtisica marina*, *Corophium volutator*, *Microdeutopus gryllotalpa* and *Iphinoe elisae* (Mutlu et al. 1992). The prevalence of *A. diadema* was observed in our study and many other studies (Mutlu et al. 1992; Kırıkım et al. 2006; Sezgin et al. 2010b). *A. diadema*, a member of the Ampeliscidae family that occurs in all seas up to the polar ones, shows a wide distribution not only in the Turkish waters but also in the entire Black Sea due to its very good adaptation to environmental stresses (Stoykov & Uzunova 2001). In addition, *A. pseudospinimana*, which is common in Turkish waters, is an expected result in this study (Teaca & Gomoiu 2007). The prevalence and dominance of *I. tenella, P. longimanus, P. longicorne, I. elisae* and *B. guilliamsoniana* in the Black Sea is remarkable. The benthic fauna of the Black Sea is dominated by polychaetes and mollusks, followed by crustaceans. Among crustaceans, amphipods dominate and are followed by decapods and isopods (Bat et al. 2011). Similarly, amphipods are known to be the dominant crustaceans, both in terms of the number of species and the number of individuals, not only in the Black Sea but in all benthic habitats. On the other hand, cumaceans, especially the species *P. longicorne* and *I. tenella*, dominate in the soft bottom with fine grain structure and organic enrichment (Moreira et al. 2008). It is noteworthy that very few species belonging to the order Mysidacea were found in this study. Only one Mysid species was found in the Black Sea and no species were found in the Marmara Sea. This can be attributed to the grab sampling method. Tanaids were represented in the Black Sea only by species belonging to the genus *Apseudopsis*. According to Moeria et al. (2008), these species are detritivores and tolerant of organic content. They are also found in high density in ports with high metal pollution (Guerra Garcia et al. 2003). However, according to Carretero et al. (2010), *Apseudopsis latreillei* is a sensitive species and, particularly affected by discharges.

Today, species of Mediterranean origin dominate in the Black Sea ecosystem, where organisms of miscellaneous origin occur due to the influence of the straits (Finenko 2008). Some species identified in the Black Sea (*G. sanctus*, *A. pseudosarsi*, *B. guilliamsoniana*, *D. spiniventris*, *E. brasiliensis*, *M. massiliensis*, *I. tenella*, *P. longicorne*, *A. nitescens*, *B. sexdentatus* and *P. hirtellus)* were not found in the Marmara Sea during this study, even though they are known to occur there (Bakır et al. 2014; Balkıs et al. 2016).

As for the distribution of crustaceans in the Marmara Sea, Amphipoda (63%) are the largest group, followed by Decapoda (14%), Isopoda (9%), Cumacea (9%), Tanaidacea (4%) and Leptostraca (1%). According to Balkıs et al. (2016), 418 malacostracan crustacean species are known from the Marmara Sea. Of these, 195 are amphipods, 140 are decapods and the rest belong to Isopoda (42), Cumacea (18), Mysidacea (12), Tanaidacea (7), Stomatopoda (2) and Leptostraca (1). Several researchers have expressed their doubts about the presence of six species from this checklist. According to Bakır et al. (2014), *Nebalia bipes* from Leptostraca is one of these species. *Nebalia strausi* was previously reported from the Aegean Sea and the Mediterranean Sea (Koçak & Katağan 2006; Koçak et al. 2011, Bakır et al. 2014) and in this study it is reported for the first time from the Marmara Sea. Bakır et al. (2012) identified 77 crustacean species on the soft bottom of the Marmara Sea, similar to this study. Their distribution by syntaxonomic order was as follows: Amphipoda (50%), Decapoda (14%), Cumacea (6%), Tanaidacea (2%) and Mysidacea (2%). In this study, Amphipoda (63%) and Decapoda (14%) were ranked first, and were followed by Isopoda (9%), Cumacea (9%), Tanaidacea (4%) and Leptostraca (1%). As mentioned above, no species belonging to the Mysidacea order were found. Previous researchers reported the dominance of *Microdeutopus versiculatus* (Spence Bate, 1857), *Ampelisca* sp., *Apseudes* sp., *Megamphopus katagani* Bakır Sezgin & Myers, 2011 and *Monocorophium sextonae* (Crawford 1937). They found that the species with the highest frequency index were: *M. versiculatus*, *Apseudes* sp. (40.7%), *Leptochelia dubia* (Kroyer 1842), *Phtisica marina* Slabber, 1769, *Harpinia crenulata* (Boeck 1871) and *Ampelisca pseudospinimana* Bellan-Santini & Kaim-Malka, 1977 (Bakır, 2012). According to our findings, the species with the highest frequency in the Marmara Sea are *A. diadema* (52%) and *I. trispinosa* (67%), followed by *A. planierensis*, *A. pseudospinimana*, *G. palmata*, *P. longimanus*, *P. marina* and *A. acutifrons*. The species with the highest dominance index are *Apocorophium acutum* (27.5%) and *Microdeutopus gryllotalpa* (14.1%). *M. gryllotalpa* is known for its tolerance to a wide range of salinity. This species, which occurs in many different habitats, can dominate in both sea meadows and regions with high levels of organic content (Drake & Arias 1995; Carvalho et al. 2006; Cacabelos et al. 2010). In the Marmara Sea, which consists of two layers of water with varying salinity and is under pressure of pollution, the dominance of this species may be related to its ecological tolerance. Similarly, *A. acutum* is a detritivore species whose abundance increases with organic content and occurs in many different ecosystems (Chintiroglou et al. 2004; Doğan et al. 2008). We observed a significant increase in the number of individuals of *A. acutum* (7903), *A. latreillii* (6653), *M. gryllotalpa* (4070) and *P. marina* (963) in the Istanbul Strait (site B2). Hydrodynamic processes are known to have a particular effect on the distribution of macrobenthic fauna, especially in the Istanbul Strait (Uysal et al. 2002). The high abundance in the Istanbul Strait, observed in this study, may be related to the species resistance to hydrodynamic conditions (Moyano & Gomez 1998). In addition, opportunistic pollution indicator species are known to increase in number under ecological pressure (Lo Brutto et al. 2016). These species are also known to tolerate organic pollution (Aslan-Cihangir & Pancucci-Papadopoulou 2011; Srinivas et al. 2019).

We recorded two species in the Marmara Sea, which are new to the Turkish seas. *Kupellonura mediterranea*, which is an isopod originating from the Mediterranean and Red seas, is distributed in the Mediterranean at a depth of 70–880 m (Barnard 1925; Wägele 1981). However, the fact that Barranco et al. (2012) found this species in the Cerro Gordo cave in Spain proves its wide distribution. *Leucon* (*Macrauloleucon*) *siphonatus* is a cumacean species (Watling 1991) known from the Northeast Atlantic, the Mediterranean and the Gulf of Mexico (Băcescu 1988; Petrescu & Heard 2010).

When analyzing the H' values, we note that some sites scored zero values. These zero values apply only to crustacean diversity and do not reflect macrobenthic diversity as a whole. However, we cannot ignore the fact that peracarid crustaceans in particular are good bioindicators of ecological conditions (Conradi et al. 1997; Chintiroglou et al. 2004; Moreira et al. 2008; Ambrosio et al. 2014; Podlesińska & Dąbrowska 2019). According to Bellan-Santini (1981), H' values between 0.16 and 1.96 indicate ecosystems under pollution pressure, while a range of 2.4–4.6 is normal for uncontaminated environments (Chintiroglou et al. 2004).

Accordingly, seven out of 20 sites (Sakarya – TRK10, Karadeniz Ereğlisi – TRKE1, Bartın – TRK16, Yeşilırmak – TRK37, Giresun – TRK46, Trabzon – TRK53, Hopa – TRK61) sampled in the Black Sea belong to the above-mentioned first group. In the Marmara Sea, 13 out of 27 sites sampled (Izmit Bay – Z7, IZ30, Pendik – MY1, Yassıada – YSA, Küçükçekmece – KC1, Bandırma – BK1, Bayramdere – MD19A, Susuruk Stream – SD2, Gemlik – MD22A, GK1, Yalova – MD24, Erdek – ER1) are in the first group under pollution pressure. The situation in Izmit Bay, on the Küçükçekmece shore and at the Yassıada sites in the Marmara Sea ($H' = 0$) is particularly noteworthy. Bakır et al. (2012) also reported low diversity of crustaceans in Izmit Bay and linked it to pollution.

Many alien species are known to live in the Black Sea, which has a wide variety of habitats, but these species were not found in this study (Bat et al. 2011; *Bilgin 2019*). *K. mediterranea* was the only alien species found in the Marmara Sea (Çınar et al. 2005).

The Giresun and Hopa sites in the Eastern Black Sea region, with the highest similarity observed in the Black Sea, had a habitat structure consisting of mud. *I. tenella*, *A. pseudospinimana* and *P. longimanus* contributed to the similarity between these sites. The second highest similarity was observed at the sites in Ordu (shells and sand) and Rize (shells and mud). *A. pseudospinimana*, *A. acutum* and *P. longicorne* contributed most to their similarity. The highest similarity in the Marmara Sea was found for Yassıada (clay and fine sand) and the sites in Gemlik Bay (mud). Another similar group comprises the Büyükçekmece shore (clay and fine sand), Gemlik Bay (mud and shells) and the Kurşunlu shore (mud and fine sand). Peracarid species alone account for this similarity. The structure of habitats at the similar sites is also similar. The type of sediment is the primary factor affecting the distribution of peracarids, but there are many other important factors such as temperature, salinity, organic matter accumulation, food availability and pollution (Lourido et al. 2008). Correlating the similarities between the surveyed sites with the sediment structure alone is insufficient.

This study presents the current status of the crustacean fauna in the Black and Marmara seas along with information on the species distribution. The study has added to the knowledge about benthic biodiversity of both seas, which is now greater with the new recorded species.

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