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Research Article

Spatial and temporal variation of echinoderm assemblages from soft bottoms of the Çanakkale Strait (Turkish Strait System) with a taxonomic key of the genus *Amphiura* (Echinodermata: Ophiuroidea)

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Abstract: This study deals with the structure of echinoderm assemblages and their relationships with the biotic and abiotic conditions in the Çanakkale Strait in 2006 and 2007. A total of 25 echinoderm species were found, 4 species of which [*Amphiura securigera* (Düben & Koren, 1846); *Amphiura lacazei* Guille, 1976; *Amphiura cherbonnieri* Guille, 1972; and *Thyone fusus* (O.F. Müller, 1776)] were new records for Turkish fauna; 1 species [*Ophiopsila annulosa* (M. Sars, 1859)] was new for the Turkish Strait System; and 22 species were first reports for the Çanakkale Strait. *Echinocyamus pusillus* (O.F. Müller, 1776), *Amphipholis squamata* (Delle Chiaje, 1829), and *Ophiothrix fragilis* (Abildgaard, 1789) were the most important species, representing 71% of the total abundance. Ophiuroids were found to be the dominant group, but asteroids also played a significant role in the echinoderm community structure. No seasonal differences were found, while finer sediments and the percentage of organic carbon (TOC) seemed to encourage echinoderm behavior. Hydrodynamism seems to be the factor regulating benthic assemblages' structure and distribution in the Çanakkale Strait. An identification key to the Mediterranean species of the genus *Amphiura* is provided.

Key words: Soft bottoms, qualitative distribution, quantitative distribution, *Amphiura* identification key

Çanakkale Boğazı (Türk Boğazlar Sistemi) yumuşak zemin echinoderm topluluğunun alana ve zamana bağlı değişimi ve *Amphiura* (Echinodermata: Ophiuroidea) cinsinin tayin anahtarı

Özet: Bu çalışmada, 2006 ve 2007 yıllarında Çanakkale Boğazı'nın echinoderm topluluklarının biyotik ve abiyotik koşullarla olan ilişkileri araştırılmıştır. Çalışmada toplam olarak 25 echinoderm türü bulunmuş olup; *Amphiura securigera* (Düben & Koren, 1846), *Amphiura lacazei* Guille, 1976, *Amphiura cherbonnieri* Guille, 1972 ve *Thyone fusus* (O.F. Müller, 1776) türleri Türkiye faunası için, *Ophiopsila annulosa* (M. Sars, 1859) türü Türk Boğazlar Sistemi için ve 22 echinoderm türü ise Çanakkale Boğazı için yeni kayıttır. Belirlenen türlerden *Echinocyamus pusillus* (O.F. Müller, 1776),

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Amphipholis squamata (Delle Chiaje, 1829) ve *Ophiothrix fragilis* (Abildgaard, 1789) türleri echinoderm kommunitenin %71'ini oluşturmaktadırlar. Kommunitede Ophiuroidler dominant grubu oluştururken Asteroidler de yapısal olarak önemli rol oynamıştır. Türlerin dağılımında mevsimsel bir farklılık görülmeyip ancak küçük taneli sediment ve sedimentin TOC miktarının echinoderm türlerinin dağılımında önemli oldukları saptanmıştır. Bentik türlerin dağılımı ve yapısının belirlenmesinde, Çanakkale Boğazı'nın hidrodinamik özelliklerinin bir stress faktörü olduğu görülmüştür. Akdeniz'de bulunan Amphiura türlerinin tayin anahtarı da ayrıca verilmiştir.

Anahtar sözcükler: Yumuşak zemin, nitel dağılım, nicel dağılım, *Amphiura* tayin anahtarı

Introduction

The echinoderm fauna of Turkey consists of 82 species (Ünsal, 1973; Balkıs, 1992; Özaydın et al., 1995; Albayrak, 1996; Zaitsev and Öztürk, 2001; Çinar et al., 2002; Yokeş and Galil, 2006; Stöhr et al., 2010). According to these studies, 20 species belong to Ophiuroidea, 2 species to Crinoidea, 22 species are Asteroidea, 18 species are Holothuroidea, and 20 species are Echinoidea. The overall number is probably going to be revised, as it seems that misidentifications occurred and were retained over time. For example, in all these studies *Ophiothrix quinquemaculata* (Delle Chiaje, 1828) and *Ophiothrix fragilis* (Abildgaard, 1789), joined into a single species since 1964 (Guille, 1964), have been reported as different species. The highest number of echinoderm species has been reported from the Turkish Aegean Sea (71 species), followed by 51 species from the Marmara Sea, 44 species from the Turkish Mediterranean Sea, 19 species from the İstanbul Strait, and 14 species from the Black Sea. However, very scant data are available on the echinoderm fauna of the Çanakkale Strait (Tuncer et al., 2008).

The Çanakkale Strait, 1 of 2 straits in the Turkish Straits System, plays an important role as a biological corridor between the Mediterranean and the Black Seas and acts as an acclimatization zone for Mediterranean species (Öztürk and Öztürk, 1996). The strait, subject to high hydrodynamic conditions, is also on the route of intense maritime traffic, which severely affects the environment.

The objectives of the present study were: 1) to investigate the biodiversity of soft bottom echinoderm communities along the Çanakkale Strait; 2) to characterize the seasonal dynamics of echinoderm fauna and relate its temporal variation, if any, to abiotic compartments of the strait ecosystem; and 3) to provide a complete English identification key to the Mediterranean species of the genus *Amphiura*, including species probably overlooked in the past.

Materials and methods

Study area

The Çanakkale Strait has an approximate length of 70 km, an average width of 3.5 km, and a depth of 55 m. It consists of 2 water layers of Black Sea and Mediterranean origin, respectively. The upper layer water mass enters into the Çanakkale Strait from the Marmara Sea. Relatively uniform conditions prevail in the upper half of the Çanakkale Strait but at Cape Nara the upper layer experiences intense vertical mixing when joining the Aegean Sea, generating a thin layer of less than 10 m depth with salinity of 25.0-28.0 psu and temperatures that vary with the season. The relatively dense Mediterranean underflow enters the Çanakkale Strait below a depth of 10-15 m with stable salinity (38.9-39.0 psu) and temperature (16-17 °C; Oğuz and Sur, 1989). The surface layer in the Çanakkale Strait flows towards the Aegean Sea at velocities of 50-200 cm s^{-1}. The bottom layer moves in the opposite direction, towards the Sea of Marmara, with velocities ranging from 20-40 cm s^{-1} (Ergin et al., 1991). About 1257 km^3 of colder and fresher water flows annually into the Aegean Sea whilst, at the same time, 957 km^3 of the more saline Aegean Sea water enters the Sea of Marmara through the Çanakkale Strait (Ünlüata et al., 1990).

Sampling design

Soft bottom samples come from 2 different campaigns carried out in the Çanakkale Strait. The first was carried out seasonally during 2006 by means of a 0.1 m^2 van Veen grab at 11 stations; 6 of these stations were located along the European shelf and the remaining 5 were on the Asian shelf (Figure 1a).

Samples were collected from depths of 10-22 m from the RV *Bilim 1*. At each station, 3 replicates were taken for benthic analysis and an additional sample was collected for chemical and granulometric analyses of sediments. In addition, 7 more stations located on the mid-line of the Çanakkale Strait were sampled by means of 0.1 m^2 van Veen grab, Charcot dredge, and box-corer; these samples were obtained from the RV *K. Piri Reis* on 22.06.2007 and were drawn from depths of 40-83 m (Figure 1b). Because of the high water hydrodynamism, the sampling gear's capacity was very low. Moreover, maritime traffic did not permit long stays at each station. Therefore, although a total of 12 samples were taken in the strait's mid-line, they cannot be considered replicates and have been used in this study only for qualitative analyses. It should be pointed out, however, that the present study is the first attempt to obtain benthic samples from this area. Coordinates, depth, and information on the sampling gear used as well as sediment types are given in Table 1.

All benthic samples were sieved through a 0.5 mm mesh and fixed with a 4% formaldehyde-sea water solution. In the laboratory, the echinoderms were

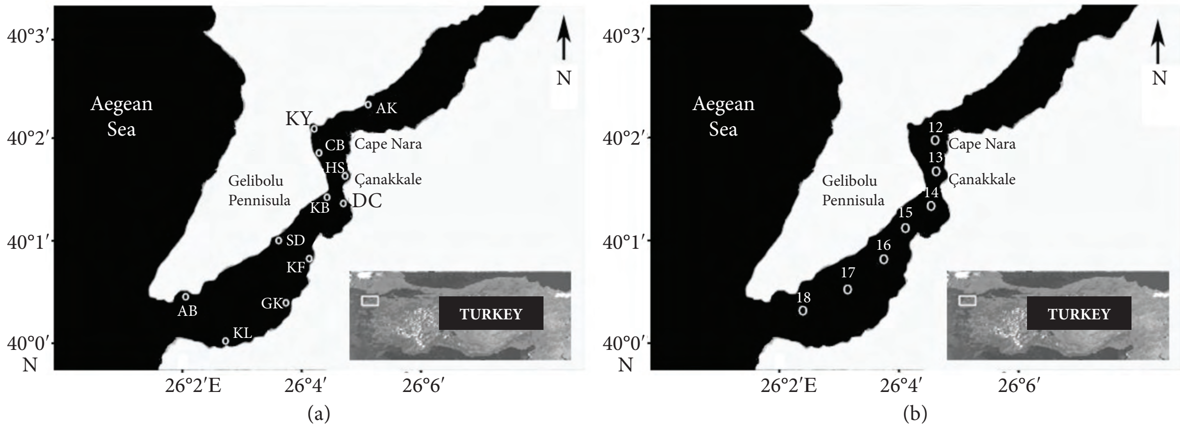

Figure 1. A map of the sites sampled in the Çanakkale Strait; **a.** coastal sites (seasonal samplings), **b.** mid-line area (sampled in June 2007) (from Aslan-Cihangir and Pancucci-Papadopoulou, 2011).

Table 1. Collection data for stations in the Çanakkale Strait (from Aslan-Cihangir and Pancucci-Papadopoulou, 2011).

Station	Coordinates	Depth (m)	Tools	Sediment type
AK	40°13′605″N, 26°25′735″E	19	grab	sandy + muddy + stone
KY	40°12′094″N, 26°22′005″E	12	grab	sandy + detritus (shell)
CB	40°10′395″N, 26°22′082″E	15	grab	sand + *Mytilus galloprovincialis* community
KB	40°08′296″N, 26°22′436″E	10	grab	sandy + detritus (shell)
SD	40°05′923″N, 26°19′004″E	15	grab	sandy + *Posidonia oceanica*
AB	40°02′960″N, 26°12′544″E	13	grab	sandy + *Posidonia oceanica*
KL	40°00′252″N, 26°14′884″E	22	grab	muddy
GK	40°02′409″N, 26°20′011″E	20	grab	muddy
KF	40°04′988″N, 26°21′490″E	18	grab	muddy
DC	40°07′783″N, 26°23′786″E	19	grab	sandy
HS	40°09′500″N, 26°24′000″E	21	grab	sandy + stone
12	40°11′603″N, 26°23′366″E	60	grab, dredge	stone
13	40°10′026″N, 26°23′548″E	83	grab	gravel
14	40°07′663″N, 26°23′145″E	81	grab	sandy
15	40°06′065″N, 26°20′000″E	40	dredge, box-corer	sandy
16	40°04′333″N, 26°18′668″E	60	box-corer	muddy
17	40°03′593″N, 26°16′614″E	69	box-corer	muddy
18	40°01′749″N, 26°13′342″E	83	box-corer	muddy

separated under a stereomicroscope and preserved in 70% ethanol. Specimens were identified and counted and the total wet weight of each species was estimated by using a balance with 0.0001 sensitivity. Each echinoderm species was assigned to a feeding type after thorough research of the available literature, including articles on single species as well as comprehensive works on the issue (e.g., Jangoux and Lawrence, 1982). The feeding types considered include carnivores, suspension feeders, deposit feeders, omnivores, and grazers.

Water for hydrographic data was collected with Nansen bottles at 2 layers (surface and bottom) of the water column. Temperature, salinity, dissolved oxygen concentration (DO), pH, total dissolved solids (TDS), and conductivity were measured on board using the YSI 556 Multiprobe system. In addition, the visibility (Secchi disc depth) was determined at each station.

Regarding the sediment samples, granulometric analyses were performed following Lewis (1984). The percentage of organic carbon (TOC) was determined spectrophotometrically in sediment samples following the sulphochromic oxidation method (HACH Publication, 1988). The amount of total nitrogen (TN) was measured by Kjeldahl's method. Unfortunately, due to several technical problems, some parameters are missing including the bottom water parameters at all stations in summer, DO value of all stations, and all parameters at stations KL, GK, DC, and HS in winter (Aslan-Cihangir and Pancucci-Papadopoulou, 2011).

Data analysis

In order to test for potential spatial and temporal differences in the echinoderm community, 2 different statistical methods were used based on the null hypothesis of no difference in the echinoderm assemblage among the 11 stations.

Univariate analysis

Univariate analyses were applied to characterize the community in terms of relative abundance and diversity. Species number (S), Abundance (N), Margalef's richness index (d), Pielou's evenness index (J'), and Shannon-Wiener's diversity index ($\log_2$ base) (H') were calculated for each station and season. The frequency of occurrence (Ci) of the species was calculated to discriminate the most representative species, as described by Soyer (1970), and results were evaluated as constant ($1 \geq Ci \geq 0.5$), common ($0.5 > Ci \geq 0.25$), or rare ($Ci < 0.25$) species. The dominance index (Di, relative total abundance in percentage) and the hierarchical importance of each species (given by the product Ci × Di) was also calculated (López de la Rosa et al., 2002). The index of dispersion (Taylor, 1961) was applied to all data to test the randomness.

Spearman's rank correlation coefficient was used in order to determine correlation between biotic and abiotic parameters. The temporal trends at each station were tested using one-way ANOVA.

Multivariate analysis

Multivariate analyses were applied to compare the community structures between stations and sampling season, and to link abiotic factors with species composition.

The numerical abundance data were analyzed using cluster and multidimensional scaling (MDS) techniques, based on Bray Curtis similarity, using the PRIMER package ver. 5.0 (Clarke and Warwick, 2001). The $\log_{10}(x + 1)$ transformation was applied, according to Taylor's Power Law method concepts (Taylor, 1961). The one-way ANOSIM permutation test was used to assess significant differences between pre-defined groups of sample sites in the cluster analyses. SIMPER analysis was performed to identify the percentage contribution of each species to the overall similarity/dissimilarity within/among the groups identified from the cluster analysis.

Results

Physical and chemical water features

Table 2 shows the mean annual values of physical parameters for each coastal station. Detailed seasonal values, not shown here, have been included in Aslan-Cihangir and Pancucci-Papadopoulou (2011). Significant fluctuations of temperature and salinity were noted, both seasonally and geographically. As can be observed, both surface and bottom temperatures were lower along the European coast (Stations AK – AB), with the exception of surface temperature of station KB, due to a peak detected in spring. It is

Table 2. A summary of environmental variables for all stations in the study area. Both the mean ± standard variation (SE mean) and number of measurements (n) are provided (derived from Aslan-Cihangir and Pancucci-Papadopoulou, 2011).

Station	Turbidity (m)	Surface temp. (°C)	Bottom temp. (°C)	Surface salinity (psu)	Bottom salinity (psu)	Surface TDS (g L-1)	Bottom TDS (g L-1)	Surface DO (mg L-1)	Bottom DO (mg L-1)
AK	8.50 ± 1.62 (n = 4)	14.91 ± 2.69 (n = 4)	12.78 ± 2.35 (n = 3)	24.48 ± 0.85 (n = 4)	26.77 ± 1.68 (n = 3)	24.43 ± 0.81 (n = 4)	27.23 ± 2.61 (n = 2)	7.12 ± 0.43 (n = 3)	6.42 ± 0.44 (n = 2)
KY	8.50 ± 1.57 (n = 4)	14.83 ± 2.81 (n = 4)	12.51 ± 2.26 (n = 3)	24.61 ± 0.85 (n = 4)	25.48 ± 0.78 (n = 3)	25.14 ± 0.87 (n = 4)	25.93 ± 0.73 (n = 3)	7.29 ± 0.58 (n = 3)	8.22 ± 0.86 (n = 2)
CB	7.80 ± 1.80 (n = 4)	14.83 ± 2.76 (n = 4)	12.77 ± 2.23 (n = 3)	24.62 ± 0.88 (n = 4)	25.44 ± 0.71 (n = 3)	25.18 ± 0.86 (n = 4)	26.01 ± 0.76 (n = 3)	7.4 ± 0.85 (n = 3)	7.31 ± 0.82 (n = 2)
KB	7.88 ± 1.94 (n = 4)	16.20 ± 2.82 (n = 4)	14.51 ± 2.27 (n = 3)	26.36 ± 0.93 (n = 4)	31.45 ± 1.46 (n = 3)	26.77 ± 0.89 (n = 4)	31.35 ± 1.33 (n = 3)	7.34 ± 1.10 (n = 2)	6.57 ± 1.67 (n = 2)
SD	9.43 ± 1.29 (n = 4)	14.79 ± 2.26 (n = 4)	13.68 ± 1.40 (n = 3)	27.16 ± 0.50 (n = 4)	31.85 ± 2.86 (n = 3)	27.48 ± 0.53 (n = 4)	31.69 ± 2.55 (n = 3)	7.64 ± 1.45 (n = 4)	6.98 ± 1.70 (n = 3)
AB	8.13 ± 1.23 (n = 4)	14.71 ± 2.37 (n = 4)	13.79 ± 0.98 (n = 3)	27.39 ± 0.59 (n = 4)	33.65 ± 1.27 (n = 3)	27.72 ± 057 (n = 4)	33.33 ± 1.15 (n = 3)	8.22 ± 1.77 (n = 3)	7.97 ± 2.39 (n = 2)
KL	8.75± 1.09 (n = 4)	17.54 ± 1.77 (n = 3)	16.06 ± 0.64 (n = 2)	28.37 ± 0.28 (n = 3)	36.94 ± 0.96 (n = 2)	28.54 ± 0.26 (n = 3)	36.14 ± 0.87 (n = 2)	11.67 ± 0.75 (n = 2)	9.12 (n = 1)
GK	9.50 ± 1.71 (n = 4)	17.56 ± 1.88 (n = 3)	15.93 ± 0.57 (n = 2)	29.28 ± 0.19 (n = 3)	38.35 ± 0.50 (n = 2)	29.33 ± 0.16 (n = 3)	37.40 ± 0.42 (n = 2)	12.05 ± 0.69 (n = 2)	9.43 (n = 1)
KF	8.75 ± 1.31 (n = 4)	15.66 ± 2.84 (n = 4)	13.78 ± 2.67 (n = 3)	27.65 ± 0.52 (n = 4)	32.99 ± 2.78 (n = 3)	28.00 ± 0.67 (n = 3)	35.07 ± 1.09 (n = 3)	7.97 ± 2.37 (n = 3)	6.82 ± 2.13 (n = 3)
DC	9.00 ± 2.02 (n = 3)	18.56 ± 2.18 (n = 3)	15.50 ± 0.42 (n = 2)	24.26 ± 0.95 (n = 3)	37.81 ± 0.25 (n = 2)	24.77 ± 0.89 (n = 3)	36.93 ± 0.21 (n = 2)	11.61 ± 2.18 (n = 2)	5.76 ± 2.18 (n = 2)
HS	9.00 ± 1.89 (n = 3)	18.49 ± 2.13 (n = 3)	17.14 ± 2.83 (n = 2)	23.84 ± 0.95 (n = 3)	24.31 ± 1.43 (n = 2)	24.39 ± 0.88 (n = 3)	24.84 ± 1.34 (n = 2)	10.15 ± 2.04 (n = 3)	8.33 ± 1.09 (n = 2)

worth mentioning the significant difference between stations AB and KL, both located at the entrance of the Strait on the European and Asian coasts, respectively. Surface water temperature ranged from 7.92 °C (winter) to 21.66 °C (summer). KY was the station where the minimum bottom temperature was observed in winter, while the maximum bottom temperature was observed in spring at station HS (19.97 °C), on the opposite side of the Strait.

With regards to salinity, bottom values were higher than surface ones at all stations. The minimum value of surface water salinity was 22.39 psu (summer, station AK, in the innermost part of the Strait), while the maximum reached 29.54 psu (autumn, station GK, in the outer part of the Strait). Bottom water salinity ranged between 22.88 psu (spring, station HS) and 38.85 psu (spring, station GK). These strong variations were due to the mixing of the 2 distinct water masses circulating in the Strait, the colder and less saline coming from the Black Sea and the warmer, more saline of Mediterranean origin.

The pH of surface water (data not shown) ranged between 8.2 and 8.91 with respect to the season. Surface water showed higher pH than the bottom layer. The TDS of surface water showed lower values than the bottom layer, ranging from 24.43 at KY to the maximum, 29.33, at GK. Once again, values at European stations were lower than those at Asian ones. Surface DO content generally followed the same geographical pattern, with surface values higher than bottom ones at all stations. Turbidity showed a seasonal trend, decreasing from winter to spring and summer, increasing again from summer to autumn.

Sediment analysis

The TOC and TN contents of the sediment varied between 0.54 and 22.01 mg g^{-1} and 0.01 and 1.01 mg g^{-1}, respectively. TOC and TN increased through summer and autumn (Table 3) (derived from Aslan-Cihangir and Pancucci-Papadopoulou, 2011).

Sandy bottoms were the dominant substrate among the stations during the whole year (Figure 2). However, the granulometric composition of the sediments displayed considerable seasonal variations for each station, with coarser sediment in winter and spring and finer in summer and autumn. Gravely bottom was dominant only at KY in winter (45% medium gravel, 35% fine gravel). The highest percentage of silt bottoms was obtained in autumn from HS (70%) and in summer from KF (80%). Clay fraction was only present at stations AK, KF, GK, and KL in summer and autumn, ranging between 1% and 5% (Aslan-Cihangir and Pancucci-Papadopoulou, 2011).

Table 3. Seasonal total organic carbon (TOC) and total nitrogen (TN) contents of sampled sediments in mg g^{-1}. *: not available data (derived from Aslan-Cihangir and Pancucci-Papadopoulou, 2011).

Station	TOC	TN	TOC	TN	TOC	TN	TOC	TN
	WINTER		SPRING		SUMMER		AUTUMN	
AK	1.93	0.03	0.56	0.01	9.06	0.07	*	*
KY	5.73	0.36	2.34	0.03	6.62	0.03	22.01	1.01
CB	*	*	1.1	0.01	1.81	0.05	*	*
KY	0.54	0.01	0.57	0.02	1.88	1.00	*	*
SD	1.42	*	1.39	*	1.95	0.06	1.25	0.09
AB	4.45	0.08	4.49	0.04	*	*	8.80	0.06
KL	2.57	0.08	2.4	*	14.21	1.02	2.65	0.06
GK	0.54	0.02	2.78	0.07	12.26	0.04	13.23	0.20
KF	2.48	0.09	2.88	0.06	12.12	0.06	17.83	0.04
DC	*	*	0.78	0.02	2.09	0.04	1.95	0.02
HS	0.94	0.02	1.06	0.02	*	*	4.11	0.06

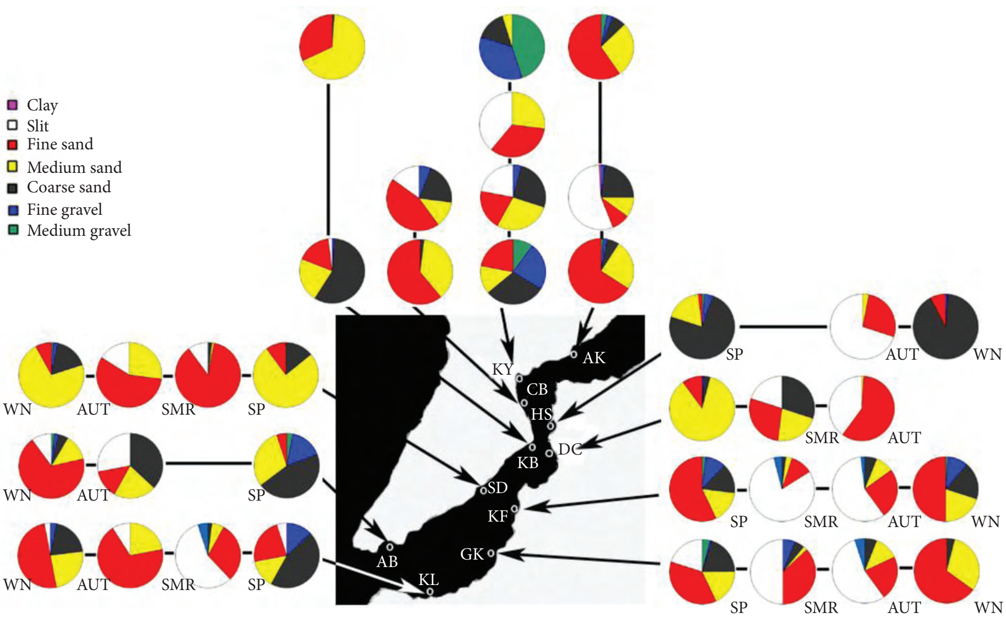

Figure 2. The seasonal sediment composition of sampled coastal stations in the Çanakkale Strait (SP, spring; SMR, summer; AUT, autumn; WN, winter) (from Aslan-Cihangir and Pancucci-Papadopoulou, 2011).

Echinoderm community

A total of 1636 ind. m^{-2} belonging to 25 species of echinoderm were caught in the study area, including 13 species of Ophiuroidea, 4 Asteroidea, 4 Echinoidea, 3 Holothuroidea, and 1 Crinoidea. Of these, 3 Ophiuroidea [namely *Amphiura cherbonnieri* Guille, 1972; *Amphiura securigera* (Düben & Koren, 1846); and *Amphiura lacazei* Guille, 1976)] and the holothuroid *Thyone fusus* (O.F. Müller, 1776) were new records for Turkish seas, while the ophiuroid *Ophiopsila annulosa* (M. Sars, 1857) was a new record for the Turkish Strait System. The remaining species (except for *Asterina gibbosa* (Pennant, 1777), *Paracentrotus lividus* (Lamarck, 1816), and *O. fragilis*) were recorded for the first time in the Çanakkale Strait during the present study (Table 4).

Table 4. List of echinoderm species collected in Çanakkale Strait. Ni: ind. m^{-2}; Ci: frequency of occurrence; Di: dominance index (%); Ci × Di: species rank of importance; * new record for Turkish Seas; ** new record for Turkish Strait System. Numbers in bold indicate the most important and characteristic species.

Species/stations	**AK**	**KY**	**CB**	**KB**	**SD**	**AB**	**KL**	**GK**	**KF**	**DC**	**HS**	**Ni**	**Ci**	**Di**	**CixDi**	**Middle line**
Crinoidea																
Leptometra phalangium (J. Müller, 1841)						3						3	0.01	0.22	0.002	
Asteroidea																
Asterias rubens Linnaeus, 1758		5									17	22	0.02	1.31	0.032	
Asterina gibbosa (Pennant, 1777)	3					10		3				16	0.03	1.09	0.035	
Astropecten irregularis (Pennant, 1777)	10											10	0.02	0.66	0.016	
Astropecten platyacanthus (Philippi, 1837)					3							3	0.01	0.22	0.002	
Ophiuroidea																
Amphipholis squamata (Delle Chiaje, 1828)		97	147	3	53		17	37	13	3	20	390	0.22	21.44	**4.632**	+
Amphiura chiajei Forbes, 1843	17	12				3	3	17	20			72	0.09	4.60	0.404	
Amphiura securigera (Düben & Koren, 1846)*						3						3	0.01	0.22	0.002	
Amphiura lacazei Guille, 1976*		5										5	0.01	0.22	0.002	
Amphiura cherbonnieri Guille, 1972*	3	5				7	7	27			5	54	0.07	3.28	0.236	
Amphiura filiformis (O.F. Müller, 1776)	3	5				30	3	7	20		5	73	0.11	4.60	0.515	+
Ophiomyxa pentagona (Lamarck, 1816)									3			3	0.01	0.22	0.002	
Ophiopsila annulosa (M. Sars, 1857)**																+
Ophiopsila aranea Forbes, 1843								3				3	0.01	0.22	0.002	+
Ophiothrix fragilis (Abildgaard, 1789)	7	245	18		10			7			7	294	0.11	17.07	**1.912**	+
Ophiura albida Forbes, 1839							20	27	20			67	0.06	4.38	0.245	
Ophiura ophiura (Linnaeus, 1758)					3							3	0.01	0.22	0.002	
Ophiuroid indet.						3						3	0.01	0.22	0.002	
Echinoidea																
Echinocyamus pusillus (O.F. Müller, 1776)		13		23	20	280	90	43	7		8	484	0.23	31.51	**7.310**	+
Genocidaris maculata A. Agassiz, 1869		3	5					7			3	18	0.05	1.31	0.063	
Paracentrotus lividus (Lamarck, 1816)			38		3			13				54	0.05	3.28	0.158	
Psammechinus microtuberculatus (Blainville, 1825)					3	17		17	10			47	0.08	3.28	0.263	
Holothuroidea																
Leptopentacta tergestina (M. Sars, 1857)								3				3	0.01	0.22	0.002	
Leptosynapta inhaerens (O.F. Müller, 1776)					3							3	0.01	0.22	0.002	
Thyone fusus (O.F. Müller, 1788)*								3				3	0.01	0.22	0.002	
No. of specimens m^{-2}	43	390	208	26	98	356	140	214	93	3	65	1637				
No. of species	6	9	4	2	8	9	6	14	7	1	7					
Biomass g m^{-2}	8.1	32.9	938.1	0.2	47.5	47.1	3.7	611.1	23.9	0.01	2.5					

Of the 25 total identified species, 19 were found along the European coast, 16 along the Asian coast, and 6 species on the mid-line of the Çanakkale Strait. *Ophiopsila annulosa* was sampled only on the strait's mid-line. A further 11 species were common to both coasts, while 5 species [*Ophiomyxa pentagona* (Lamarck, 1816); *Ophiopsila aranea* Forbes 1843; *Ophiura albida* Forbes, 1839; *Leptopentacta tergestina* (M. Sars, 1857); and *Thyone fusus*] were present only at stations located on the Asian coast and 8 [*Leptometra phalangium* (J. Müller, 1841); *Astropecten irregularis* (Pennant, 1777); *Astropecten platyacanthus* (Philippi, 1837); *Amphiura securigera*; *Amphiura lacazei*; *Ophiura ophiura* (Linneus, 1758); and *Leptosynapta inhaerens* (O.F. Müller, 1776)] were present only on the European coast. However, a strong difference in abundance was observed among stations: a total of 1121 ind. m^{-2} were sampled along the European coast (6 stations), while only 515 ind. m^{-2} were collected at the Asian coast (5 stations).

Although no species could be considered constant (Ci ≥ 0.5) or common (0.5 > Ci ≥ 0.25), the most important and characteristic species (Ci × Di > 5) was *Echinocyamus pusillus* (O.F. Muller, 1776), accounting for more than 30% of the total abundance, followed by *Amphipholis squamata* (Delle Chiaje, 1828) and *O. fragilis* (5 > Ci × Di > 1, Table 4). Together, these 3 species represented 71% of the total echinoderm abundance.

The species number (S), abundance (N), diversity (H'), species richness (d), and evenness (J) for each station and sampling season are shown in Figures 3a, b, c, d, and e. The total highest species number was found in winter and spring (15 species), followed by summer with 14 species, while the lowest species number (11 species) was found in autumn. Station GK showed the highest total number of species (14). The species number was positively correlated with the TOC content of the sediment (Spearman's rank r = 0.485) and fine gravel percentage (Spearman's rank r =

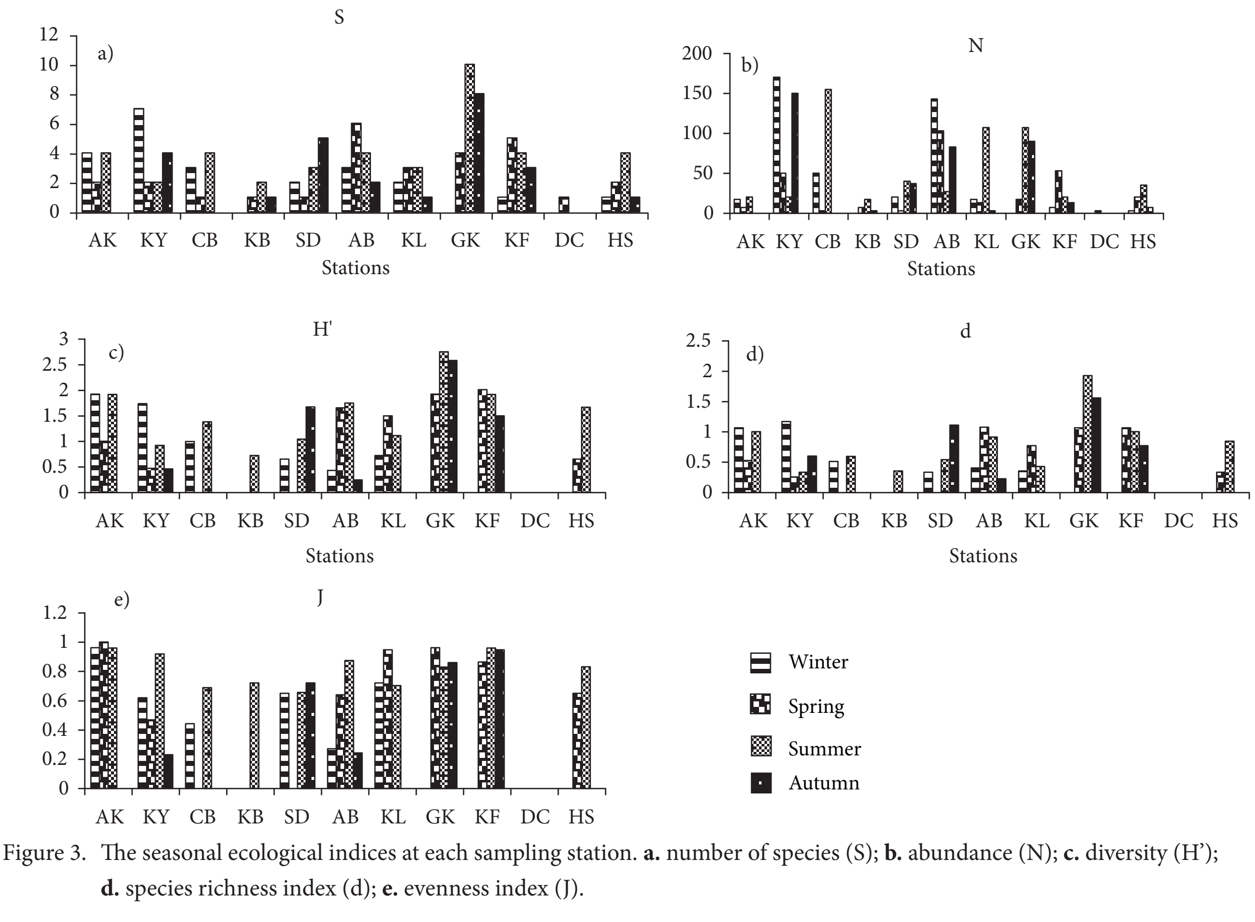

Figure 3. The seasonal ecological indices at each sampling station. **a.** number of species (S); **b.** abundance (N); **c.** diversity (H'); **d.** species richness index (d); **e.** evenness index (J).

0.356), and negatively correlated with the percentage of sand (Spearman's rank r = –0.498) at P < 0.05.

The maximum abundance of echinoderms was obtained in summer (548 ind. m^{-2}) and the minimum in spring (279 ind. m^{-2}). Station KY showed the highest abundance (390 ind. m^{-2}, with 245 of them being *O. fragilis*). The abundance of echinoderms decreased with a higher percentage of sand content (r = –0.435 at P < 0.05). On the other hand, it increased in correlation with the percentages of medium gravel (r = 0.460), fine gravel (r = 0.482), TOC (r = 0.552), and TN (r = 0.432) at P < 0.05.

The highest diversity index (H') was found in summer at GK (2.8). The diversity index was positively correlated with the TOC content of the sediment (r = 0.403), the percentages of silt and clay (r = 0.339 and 0.377, respectively), and the turbidity of the sea water (r = 0.355) at P < 0.05. In addition, it was negatively correlated with the percentage of sand (r = –0.475) at P < 0.05. A statistically significant difference was detected among stations (P = 0.048).

Species richness (d) was positively correlated with the TOC (r = 0.443), but negatively correlated with the sand percentage (r = –0.475). It was also significantly different among stations (P = 0.049).

The highest evenness (J) value (1) was found in spring at station AK. Evenness was positively correlated with TOC (r = 0.298) and turbidity (r = 0.37). In addition, the index revealed a significant seasonal difference (P = 0.017).

A total biomass of 1714.98 g m^{-2} was measured. The highest biomass was obtained in summer (1000.44 g m^{-2}), followed by autumn with 632.69 g m^{-2}, although no specimens were collected from station CB. The other seasons were represented by very low biomass values (winter, 47.38 g m^{-2}; spring, 34.47 g m^{-2}). The highest biomass was observed at station CB in summer (920.81 g m^{-2}) because of the presence of *P. lividus* (35 ind. m^{-2}, 919.5 g m^{-2}). The biomass of echinoderms was positively correlated with the percentage of clay in the sediment (r = 0.573, P < 0.05).

Mean individual size, obtained by comparing seasonal abundance and biomass, ranged between 0.1 in winter and spring and 1.8 in summer, and was found to decrease slightly in autumn (1.6).

The cluster analysis of species abundance for each station and season based on the Bray-Curtis similarity (Figure 4) showed no clear seasonal patterns among stations. Only summer samples from stations KL, KB, and KF (60% similarity level, common presence of *E. pusillus* and *A. squamata*) and autumn samples from stations SD and GK (55% similarity level, common presence of *E. pusillus*, *O. fragilis*, *Psammechinus microtuberculatus*, and *A. squamata*) showed a somewhat seasonal pattern. In addition, stations SD and HS (spring) were totally isolated from all the others, due to the presence of a unique species in both of them (*A. platycanthus* and *A. rubens*, respectively).

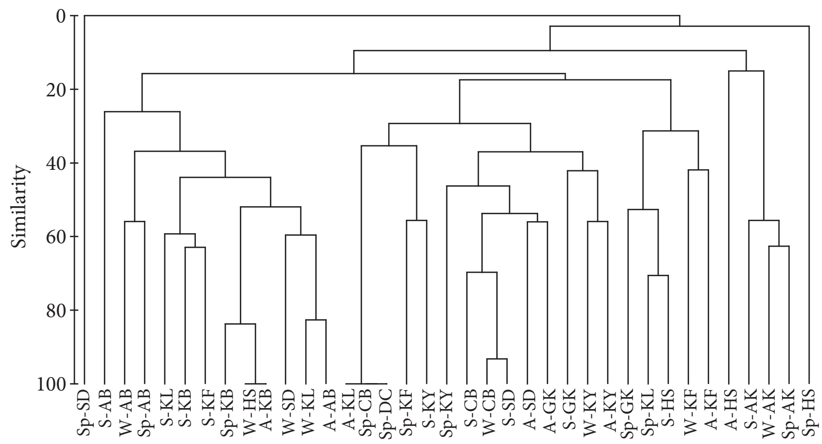

Figure 4. Seasonal cluster analysis based on the total species abundance at each coastal station. A, autumn, Sp, spring, S, summer, W, winter.

According to the cluster analyses applied to the total abundance of echinoderms, 3 groups of stations were detected in the area (Figure 5). Similarity values higher than 45% were calculated within groups I (48%), II (52%), and III (55%). The species that contributed most to the similarity of these groups according to the SIMPER analysis was *A. squamata* (contribution: 100%, 51%, and 26%, respectively).

According to ANOSIM (Table 5), the rate of dissimilarity among groups was statistically significant between the first and third group, and between the second and third (R = 0.8, P = 0.048; R = 0.964, P = 0.048).

Most abundant species

Differences were observed in the distribution of the most abundant species among stations. As shown in Figure 6, while *Ophiothrix fragilis* abundance was quite significant in the innermost part of the strait (up to 245 ind. m^{-2} at station KY), its presence was negligible at the remaining stations (only 7 ind. m^{-2} at stations GK and HS). *Echinocyamus pusillus*, in contrast, had low abundance at almost all of the stations, with the exception of those situated in the outermost part of the strait, and reached its maximum abundance at the "entrance" stations AB and KL, followed by GK, on the eastern coasts. *Amphipholis*

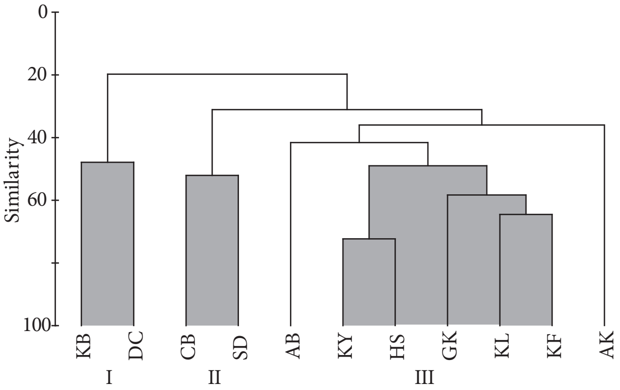

Figure 5. Cluster analysis based on the total species abundance at each coastal station.

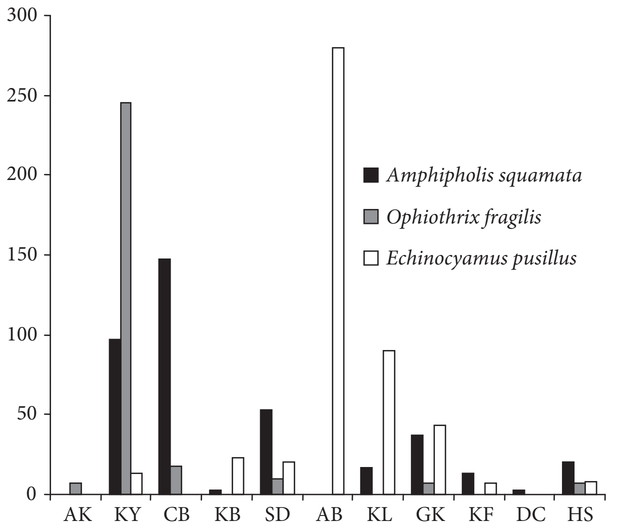

Figure 6. The abundance and distribution of the 3 most abundant species in the study area.

Table 5. Results of ANOSIM and SIMPER on the total data sets.

Groups	One-way ANOSIM		SIMPER		
	R value	P value	Average dissimilarity (%)	Discriminating species	Contribution (%)
I vs. II	1.0	0.33	76.47	*Amphipholis squamata* *Ophiotrix fragilis* *Paracentrotus lividus*	22.52 19.82 19.57
I vs. III	0.964	0.048**	76.23	*Echinocyamus pusillus* *Amphiura filiformis* *Ophiura albida*	12.03 11.73 10.56
II vs. III	0.8	0.048**	61.85	*Paracentrotus lividus* *Amphiura filiformis* *Echinocyamus pusillus*	11.10 9.31 9.29

squamata, even though common to almost all of the studied stations, was clearly most abundant along the European coasts but absent from the outermost station, AB. It is worth mentioning the almost total absence of these species at station AK, which was instead dominated by *Astropecten irregularis* and *Amphiura chiajei*. The maximum abundance was for *O. fragilis* in autumn, *A. squamata* in summer, and *E. pusillus* in winter.

Feeding types

The most important feeding types in the area were surface deposit feeders (45%) and carnivores (31%), followed by suspension feeders (19%), and grazers (4%), while only 1% could be considered omnivores.

Cluster analysis applied to the relative abundance of feeding type (Figure 7) showed 3 stations (DC, KB, and CB) that were isolated due to their paucity (stations KB and DC) or to the dominance of a single feeding type derived from the presence of a single dominant species (*A. squamata*, station CB). The remaining stations were all grouped at a similarity level of approximately 80%, discriminating several groups. A group including stations AB and GK, hosting all feeding types, is separated from a second one (including stations KY, HS, SD, and KF) characterized by the absence of omnivores, while the last group (stations AK and KL) is characterized by the absence of grazers.

Discussion

Faunistic analyses of the echinoderm community in the soft bottom of the Çanakkale Strait revealed the presence of 25 species and a total of 1636 ind. m^{-2}. The dominant group was Ophiuroidea with 970 ind. m^{-2},

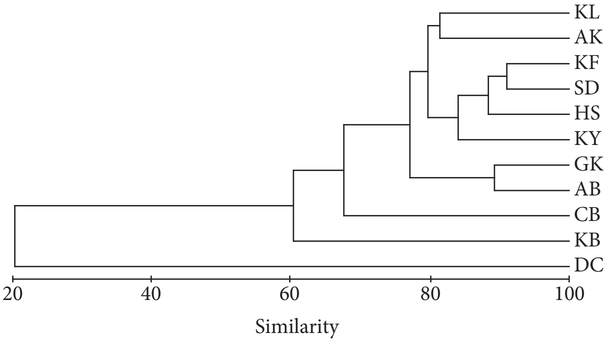

Figure 7. Cluster analysis according to feeding type.

followed by Echinoidea (603 ind. m^{-2}), Asteroidea (51 ind. m^{-2}), Holothuroidea (9 ind. m^{-2}), and Crinoidea (3 ind. m^{-2}). These differences may be explained by the methodology used, as the van Veen grab provides mainly infaunal echinoderms species like ophiuroids, but is insufficient for the study of epibenthic fauna requiring the use of dredges (Shin and Koh, 1993).

The total abundance and biomass showed their maximum in summer and minimum in spring (548 ind. m^{-2} and 1000.44 g m^{-2} in summer; 278 ind. m^{-2} and 34.47 g m^{-2} in spring), while the other seasons showed intermediate values. Most echinoderms are reported as having their breeding period in the summer and settlement of juveniles during winter and spring. This pattern was also revealed to be followed in the studied area. When comparing seasonal abundance and biomass, large echinoderms seem to be represented during summer and autumn, while small specimens are present during winter and spring. The decrease in abundance and biomass from winter to spring may also be due to high post-settlement mortality. In addition, the cause of decreasing total abundance from summer to autumn could be factors such as the regression of algae and pressure by predators (Lourido et al., 2008).

We found that the number of species, abundance, biodiversity, and species richness tended to be lower in fine sand bottoms. The same results were obtained for peracarid and decapod assemblages in the same area (Aslan-Cihangir and Pancucci-Papadopolou, 2011). Reduced diversity of benthic assemblages in sandy substrata has been reported in stressed conditions (Vanosmael et al., 1982). It is also known that the number of species and abundance are higher in fine sand bottoms (Biernbaum, 1979; Marques and Bellan-Santini, 1993; Dauvin et al., 1994; Lourido et al., 2008). On the other hand, Mucha and Costa (1999) showed that hydrodynamism appears to be a stabilizing factor for macrobenthic assemblages. Strong hydrodynamism, decreasing organic load and fine fraction sediment content, fostered less reducing conditions and, concomitantly, a decrease in nutrient reduced forms and an increase in nitrate contents in interstitial water. These conditions lead to a reduction in the disturbance state of the assemblages, with an increase in different biological variables, such as species number, biomass, and diversity. Although sediment properties change seasonally in the Çanakkale Strait, the high hydrodynamism and its 2 different current systems may justify some discrepancies in this area. Thus, hydrodynamic conditions could be considered the stabilizing factor for the echinoderm assemblages of the studied area, as currents have been previously indicated to be the most important factor determining sediments' grain size (Gray, 1974; Biernbaum, 1979).

Aydın and Sunlu (2004) reported that the TOC value is lower in the south Aegean than in the Çanakkale Strait. Dense maritime traffic, human activities, and aquaculture activities may be responsible for the increase of TOC in the study area. It is indicative that the highest TOC value was measured at station KY, where aquaculture activities have taken place in the past. Organic matter enriching surface sediments constitutes a significant food resource for zoobenthos (Hyland et al., 2005). According to the same authors' classification, TOC values are separated in 3 groups: high (>35 mg g^{-1}), low (<10 mg g^{-1}), and intermediate (between 10 and 35 mg g^{-1}) concentrations. Thus, values from the Çanakkale Strait can be accepted as low and intermediate, probably exerting a positive influence on the echinoderm assemblages of the area (such as decapod assemblages; Aslan-Cihangir and Pancucci-Papadopolou, 2011). This theory is further supported by the positive correlation of TOC with species number, abundance, biodiversity, and species richness of echinoderms.

According to all of the applied analyses, no seasonal differences were detected in echinoderm assemblages from the Çanakkale Strait. The lack of seasonal differences could be due to the complexity of biotopes, the interaction between assemblages, or to species moving between substrates (García Muñoz et al., 2008). Moreover, Mucha and Costa (1999) suggested that enrichment was observed not only in terms of phyla and species but also in terms of trophic and dynamic groups, involving a wide range of ecological behaviors. Obtained echinoderm species from the Çanakkale Strait revealed a very diverse trophic status: carnivores, deposit feeders, suspension feeders, and omnivores. Moreover, most of these species can adopt different feeding types according to the habitat, which is an advantage for survival in such a harsh environment. The geographical distribution of the 3 most important species clearly depicts the habitat requirements of each species, as *O. fragilis* is a microphagous suspension feeder well adapted to detritic bottoms, *A. squamata* is a deposit feeder probably feeding on *Mytilus galloprovincialis* (Lamarck, 1819) feces at station CB, and *E. pusillus* is a carnivorous deposit feeder well adapted to coarse sandy bottoms.

The presence of the alien Atlantic asteroid *Asterias rubens* Linnaeus, 1758, recently reported from the Black Sea (Karhan et al., 2007; Dalgiç et al., 2009), in the Sea of Marmara was confirmed by this study (Table 4). Its occurrence in the Sea of Marmara has been signaled since 1990 (Yüce and Sadler, 2000), also suggesting its introduction by shipping (Zibrowius, 2002). The species seems now to extend its distribution southward, and its discovery in the Aegean Sea is predicted for the near future. Moreover, the presence of 17 individuals at station HS seems also to confirm the invasive character of the species.

The presence of *Caulerpa racemosa* (Forsskål) J. Agardh, 1873, another invasive alien species, was detected at station KL. While its presence seems to have some impact on the peracarid and decapod crustacean assemblages (Aslan-Cihangir and Pancucci-Papadopolou, 2011) at the same station, no differences were observed for echinoderms. Conversely, in Cyprus (Zenetos et al., 1999) the increase in *C. racemosa* dominance and the decrease in *Posidonia oceanica* in the same area (Moni Bay) was followed by an increase in echinoderms (from 6% to 11%).

Out of 10 known Mediterranean *Amphiura* species, 5 are here reported for the Çanakkale Strait, 3 of them (namely *A. securigera*, *A. lacazei*, and *A. cherbonnieri*) for the first time in Turkish waters. As all of them have already been reported from the Aegean Sea (Pancucci-Papadopoulou, 1996), their presence in the study area could represent the spreading of these species from the Mediterranean. On the other hand, the possibility of misidentification cannot be excluded, as all of these species are very similar to *Amphiura chiajei*. Moreover, the lack of a specific identification key for the genus in English could be an additional reason for misidentification. Aiming to fill this serious gap, an effort was made to join all information concerning the taxonomy of the genus

Amphiura, one of the most widespread ophiuroid genera in the Mediterranean, in a single identification key, given here as an Appendix.

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References

Albayrak, S. 1996. Echinoderm Fauna of the Bosphorus (Türkiye). Oebalia, vol. XXII, 25-32.

Aslan-Cihangir, H. and Pancucci-Papadopoulou, M.A. 2011. Spatial and temporal variation of soft-bottom peracarid (Crustacea: Peracarida) infauna in the Canakkale Strait (Turkey). Medit. Mar. Sci. 12(1): 153-182.

Aydın, A. and Sunlu, U. 2004. Güney Ege Denizi sedimentlerinde karbon ve yanabilen madde düzeylerinin araştırılması. E.U. Journal of Fisheries & Aquatic Sciences 21(3-4): 229-234.

Balkıs, H. 1992. Marmara Adası littoralinin makrobentosu üzerine bir ön arastırma. İ.Ü. Deniz Bilimleri ve Coğrafya Enstitüsü Bülteni 9: 309-327.

Biernbaum, C.K. 1979. Influence of sedimentary factors on the distribution of benthic amphipods of Fishers Island Sound, Connecticut. J. Exp. Mar. Biol. Ecol. 38: 201-223.

Clarke, K.R. and Warwick, R.M. 2001. Change in Marine Communities: an approach to statistical analysis and interpretation, 2nd ed. PRIMER-E, Plymouth.

Çinar, M.E., Katagan, T., Ergen, Z. and Sezgin, M. 2002. Zoobenthos-inhabiting *Sarcotragus muscarum* (Porifera: Demospongiae) from the Aegean Sea. Hydrobiologia 482: 107-117.

Dalgiç, G., Ceylan, Y. and Şahin, C. 2009. The Atlantic starfish, *Asterias rubens* Linnaeus, 1758 (Echinodermata: Asteroidea: Asteriidae) spreads in the Black Sea. Aquatic Invasions 4(3): 485-486.

Dauvin, J., Iglesias, A. and Lorgeré, J.C. 1994. Circalittoral uprabenthic coarse sand community from the western English Channel. J. Mar. Biol. Assoc. U.K. 74: 543-562.

Ergin, M., Bodour, M.N. and Ediger, V. 1991. Distribution of surficial shelf sediments in the northeastern and southwestern parts of the Sea of Marmara: Strait and canyon regimes of the Dardanelles and Bosporous. Mar. Geol. 96: 313-340.

García Muñoz, J.E., Manjón-Cabeza, M.E. and García Raso, J.E. 2008. Decapod crustacean assemblages from littoral bottoms of the Alboran Sea (Spain west Mediterranean sea): spatial and temporal variability. Sci. Mar. 72(3): 437-449.

Gray, J.S. 1974. Animal-sediment relationships. Oceanogr. Mar. Biol. Annu. Rev.12: 223-261.

Guille, A. 1964. Contribution a l'etude de la systematique et de l'ecologie d'*Ophiothrix quinquemaculata* d. Ch. Vie Milieu XV(2): 243-308.

Jangoux, M. and Lawrence J.M. 1982. Echinoderm Nutrition. A.A. Balkema Publ., Rotterdam.

HACH. 1988. Procedures for water and waste-water analysis, Loveland, CO, USA, 392 pp.

Hyland, J., Balthis, L., Karakassis, I., Magni, P., Petrov, A., Shine, J., Vestergaard, O. and Warwick, R., 2005. Organic carbon content of sediments as an indicator of stress in the marine benthos. Mar. Ecol. Prog. Ser. 295: 91-103.

Karhan, S., Kalkan, E. and Yokeş, M.B. 2007. First record of the Atlantic starfish, *Asterias rubens* (Echinodermata: Asteroidea) from the Black Sea. JMBA2 - Biodiversity Records (Published online, available at http://www.mba.ac.uk/jmba/pdf/5663.pdf).

Lewis, D.W. 1984. Practical Sedimentology. Hutchinson Ross, Pennsylvania.

López de la Rosa, I., García Raso, J.E. and Rodríguez, A. 2002. Evolution of a decapod community (Crustacea) of shallow soft bottoms with seaweeds from southern Europe. J. Mar. Biol. Assoc. U.K. 82: 85-95.

Lourido, A., Moreira, J. and Troncoso, J.S. 2008. Assemblages of peracarid crustaceans in subtidal sediments from the Ría de Aldán (Galicia, NW Spain). Helgol. Mar Res. 62: 289-301.

Marques, J.C. and Bellan-Santini, D. 1993. Biodiversity in the ecosystem of the Portuguese continental shelf: distributional ecology and the role of benthic amphipods. Mar. Biol. 115: 555-564.

Mucha, A.P. and Costa, M.H. 1999. Macrozoobenthic community structure in two Portuguese estuaries: relationship with organic enrichment and nutrient gradients. Acta Oecol. 20(4): 363- 376.

Oğuz, T. and Sur, I. 1989. A two-layer model of water exchange through the Dardanelles Strait. Oceanol. Acta, 12(1): 23-31.

Özaydın, O., Katağan, T. and Ünsal, S. 1995. The Echinoderms of the Turkish Seas. Israel J. Zool., 41: 57-68.

Öztürk, B. and Öztürk, A. 1996. Biology of the Turkish Straits System. Dynamics of Mediterranean straits and channels. Bull. Oceanog. 17: 205-221.

Pancucci-Papadopoulou, M.A. 1996. The Echinodermata of Greece. Fauna Greciae VI. Hellenic Zoological Society, Athens.

Shin, H.C. and Koh, C.H. 1993. Distribution and abundance of ophiuroides on the continental shelf and slope of the East Sea (southwestern Sea of Japan), Korea. Mar. Biol. 115: 393-399.

Soyer, J. 1970. Bionomie benthique du plateau continental de la cote catalan Française. III. Les Peuplements de Copepodes Harpacticoides (Crustacea). Vie Milieu 21: 377-511.

Stöhr, S., Çınar, M.E. and Dağlı, E. 2010. Brittle stars (Echinodermata: Ophiuroidea) from the southern coast of Turkey (Eastern Mediterranean): New records and revision of *Amphiodia obtecta* Mortensen, 1940. Zootaxa 2483: 45-57.

Stöhr, S. and Muths, D. 2010. Morphological diagnosis of the two genetic lineages of *Acrocnida brachiata* (Echinodermata: Ophiuroidea), with description of a new species. J. Mar. Biol. Assoc. U.K. 90(4): 831-843

Taylor, L.R. 1961. Aggregation, variance and the mean. Nature 189: 732-753.

Tuncer, S., Can, N., Aslan-Cihangir, H. and Alkılıç, B. 2008. Sualtı gözlem metodu ile güney Çanakkale Boğazı makrobentik biotasının araştırılması. Türkiye'nin Kıyı ve Deniz Alanları VII. Ulusal Kongresi 433-439.

Ünlüata, U., Oğuz, T., Latif, M.A. and Özsoy, E. 1990. On the physical oceanography of the Turkish Straits. In: The Physical Oceanography of Sea Straits (ed. L. Pratt). Kluwer, Dordrecht, pp. 25-60.

Ünsal, S. 1973. Ege Denizi Türkiye karasularında yaşamakta olan derisidikenliler (Echinodermata) üzerine biyo-ekolojik araştırmalar. Ph.D thesis, Ege University, 137 pp.

Vanosmael, C., Willems, K.A., Claeys, D., Vinex, M. and Heip, C. 1982. Macobenthos of a sublittoral sandbank in the Southern Bight of the North Sea. J. Mar. Biol. Assoc. U.K. 62: 521-534.

Yokes, M.B. and Galil, B.S. 2006. The first record of the needle-spined urchin *Diadema setosum* (Leske, 1778) (Echinodermata: Echinoidea: Diadematidae) from the Mediterranean Sea. Aquatic Invasions 1(3): 188-90.

Yüce, Ö. and Sadler, K.C. 2000. Determination of the reproduction periods of two dominant starfish in the Straits and the Sea of Marmara. In: Proceedings of SBT 2000 – 4th National Meeting of Underwater Science and Technology, İstanbul, 2-3 November 2000 (eds. S. Hamarat and V. Evrin), pp. 45-49.

Zaitsev, Y. and Öztürk, B. 2001. Exotic species in the Aegean, Marmara, Black, Azov and Caspian Seas. Turkish Marine Research Foundation, İstanbul, 267 pp.

Zenetos, A., Revkov, N.K., Konsulova, T.S., Sergeeva, N., Simboura, N., Todorova, V.R. and Zaika, V.E. 1999. Coastal benthic diversity in the Black and Aegean Seas. Medit. Mar. Sci. 1/2: 105-117.

Zibrowius, H. 2002. Assessing scale and impact of ship-transported alien fauna in the Mediterranean. In CIESM, 2002 – Alien marine organisms introduced by ships in the Mediterranean and Black Sea. CIESM Workshop Monographs, no. 20, pp. 63-68, Monaco.

Appendix. Identification key to the Mediterranean species of the genus *Amphiura*. The key is applicable to adult specimens.*

Genus Amphiura.

Two infradental papillae at the top of the jaw, a wide buccal scale higher up at each side of the jaw, and an outer mouth papilla of variable shape in each mouth angle, which may be lacking.

1. Disk partly covered with scales……........……….2
- Disk completely covered with scales on both sides, presence of tentacle scales……………………..…3
2. Dorsal side of the disk covered with fine scales, ventral side naked. 1 conical, spine-like outer mouth papilla. 5-7 arm spines, the second of each group flattened and axe-shaped. No tentacle scales.……..….. *Amphiura filiformis* (O.F. Muller, 1776)
- Both dorsal and ventral surfaces of the disc naked apart from the radial shields on the dorsal surface. 3-4 arm spines, strongly flattened; the second of each group axe-shaped and widened at the tip. Single tentacle scale, minute, absent on-distal part of arm ……..…………………. *Amphiura securigera* (Duben & Koren, 1846)
3. One tentacle scale ……………..............………. 4
- Two tentacle scales ……..........................…..…... 5
- Disk with small tubercules on the margin and the ventral side, number of tentacle scales decreasing from the basis to the end of arms…………. *Acrocnida brachiata* (Montagu, 1804)
4. 1 small tentacle scale, often absent. Presence of a central 5-plate rosette on the dorsal side of the disk. Radial shields less than 1/3 of the disk radius. ………..…………..*Amphiura lacazei* Guille, 1976
- One big tentacle scale, always present. No visible central rosette. Radial shields more than 1/2 of the disk radius …………………….. *Amphiura apicula* Cherbonnier, 1957
5. Presence of a central 5-plate rosette on the dorsal side of the disk……......................................…… 6
- Absence of a central 5-plate rosette on the dorsal side of the disk ……................................………7
6. Outer mouth papilla broad, scale-like, 4-6 short, conical arm spines, 2 tentacle scales forming an acute angle.............. *Amphiura chiajei* Forbes 1843
- Outer mouth papilla big, wide. 3 arm spines, 2 tentacle scales forming an angle of 90° …………. *Amphiura cherbonnieri* Guille, 1972
7. 7-8 arm spines, short and robust …………... *Amphiura mediterranea* Lyman, 1882
- Similar to the preceding, but under arm plates wider and arm spines thicker, radial shields separated …....… *Amphiura incana* Lyman, 1879
- Presence of 2 mouth papillae ……….. *Amphiura delamarei* Cherbonnier, 1958 (only Balearic Islands)

* *Amphiura stepanovi* Dyakonov 1954 (Black Sea) was not included, while *Acrocnida brachiata* was here considered among *Amphiura* species due to its close affinities with *Amphiura chiajei* and its unclear taxonomic status. The possible discovery in the Mediterranean of a new *Acrocnida* species (*A. spatulispina*, Stöhr and Muths, 2010), recently described (Stöhr and Muths, 2010) from France's central Atlantic coast in the near future is not to be excluded.