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RESEARCH PAPER

Temporal Changes in the Polychaeta (Annelida) Community Associated with *Cystoseira* Beds of Sinop Peninsula (Southern Black Sea)

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Abstract

In order to determine seasonal trends of Polychaeta fauna associated with *Cystoseira* (*C. barbata* and *C. crinita*) facies along the Sinop Peninsula (Black Sea), a total of 9 stations were selected and sampled with scuba diving between October 2013 and July 2014, seasonally. The results of qualitative and quantitative analysis of samples, 39 species and 10,199 individuals belong to 17 families were identified. Among them, *Sabellaria spinulosa* (Leuckart, 1849) was firstly reported from the Turkish Black Sea coast. Syllidae was the most representative family in the area. The most dominant and frequent species were *Platynereis dumerillii* (Audouin & Milne Edwards, 1833) and *Salvotoria clavata* (Claparéde, 1863). The maximum number of species (27 species) was observed in autumn, the highest mean number of individuals (27,441.7 ind.m^{-2}) was counted in spring. The correlation between polychaete community associated with *Cystoseira* beds and environmental variables was strongly high (r= 0.90) according to Canonical Correspondence Analysis.

Keywords: Polychaeta, Annelida, *Cystoseira* facies, seasonal dynamic, Sinop Peninsula.

Sinop Yarımadası (Güney Karadeniz)'ndaki *Cystoseira* Yatakları ile Birliktelik Oluşturan Polychaeta (Annelida) Kommunitesindeki Zamansal Değişimler

Özet

Sinop Yarımadası (Karadeniz) kıyılarındaki *Cystoseira* (*C. barbata* ve *C. crinita*) fasiyesiyle birliktelik oluşturan Polychaeta türlerinin mevsimsel eğilimlerini tespit etmek için 9 istasyon seçilmiş ve Ekim 2013-Temmuz 2014 tarihleri arasında tüplü dalış yapılarak mevsimsel olarak örneklenmiştir. Örneklerin kalitatif ve kantitatif analizleri sonucunda, 17 familyaya ait 39 tür ve 10199 birey tanımlanmıştır. Bunlardan, *Sabellaria spinulosa* (Leuckart, 1849) Türkiye'nin Karadeniz kıyıları için ilk kayıttır. Syllidae bölgede en iyi temsil edilen familya olmuştur. En baskın ve sık türler *Platynereis dumerillii* (Audouin & Milne Edwards, 1833) ve *Salvotoria clavata* (Claparéde, 1863) olarak saptanmıştır. En yüksek tür sayısı (27 tür) sonbahar mevsiminde, en yüksek ortalama birey sayısı ise (27441,7 birey.m^{-2}) bahar mevsiminde hesaplanmıştır. *Cystoseira* yataklarıyla birliktelik oluşturan poliket kommunitesi ve çevresel değişkenler arasındaki korelasyonun Kanonik Uyum Analizine göre oldukça yüksek (r= 0.90) olduğu tespit edilmiştir.

Anahtar Kelimeler: Polychaeta, Annelida, *Cystoseira* fasiyesi, mevsimsel dinamik, Sinop Yarımadası.

Introduction

Macro algae are major components in the coastal ecosystem. They are distributed along the upper-infralittoral zone and provide substratum and food source for many marine invertebrates (Pérès, 1982; Fraschetti *et al.*, 2002). Among brown algae (Phaeophyceae), *Cystoseira* species are important shelters for polychaetes and other benthic species. The brown algae *Cystoseira* was dominant along the upper infralittoral zone of the Mediterranean (Alós, 1990; Ergen and Çinar, 1994; Fraschetti *et al.*, 2002). Coastal areas of the Black Sea provide natural habitats for *Cystoseira barbata* and *C. crinita*, two structure-forming species of benthic phytocenoses (Ryabushko *et al.*, 2014). *Cystoseira* species has widespread distribution among the Black Sea and beds of *C. barbata* constituted a very important ecological role for the marine organisms in the rocky infralittoral zone. Nevertheless, *Cystoseira* biomass was dramatically declined during last several decades in the different coastal regions of the Black Sea

(Bulgaria, Romania, Ukrania and Russia) (Gozler *et al.*, 2010).

Several numbers of studies were carried out on the species associations on *Cystoseira* facies (Milovidova, 1966; Tigãnus, 1972; Andriescu, 1977; Ergen and Çinar, 1994; Gozler *et al.*, 2010) up to date in the Mediterranean and the Black Sea. However, the knowledge about the latest status of *Cystoseira* species and their relations with benthic invertebrates along the Turkish Black Sea coast is very limited. Çinar and Gonlugur-Demirci (2005) examined polychaete assemblages of different biotopes as *C. barbata*, *Ulva rigida* and *Mytilus galloprovincialis* in the Sinop Peninsula. The community structure of benthic invertebrates associated with *C. barbata* was studied by Gozler *et al.* (2010) in the Eastern Black Sea coast of Turkey. As seen from mentioned studies above, Polychaeta community structure of *Cystoseira* facies is poorly known and seasonal fluctuations of community components and their correlations with environmental variables are unknown.

The aims of the present study are to identify Polychaeta species associated with *Cystoseira* facies; to determine their intra-annual temporal variation seasonal dynamics and to study any possible correlation between environmental variables and polychaete community.

Materials and Methods

Sampling and Laboratory Procedures

Cystoseira barbata and *C. crinita* facies were collected at 9 stations between October 2013 and July 2014, seasonally in the Sinop Peninsula (Figure 1, Table 1). Macro algae samples were collected by scuba diving using a quadrant of 20x20 cm at a depth of 2-5 meter. At each station, three replicate were collected every season. On the board, algae samples were sieved through 0.5 mm mesh and the retained material was placed in separate jars containing 4% seawater formaldehyde solution.

In the laboratory, samples were rinsed in fresh water and sorted according to taxonomic groups under a stereomicroscope, and preserved in 70% ethanol. Afterwards polychaetes were identified and counted under stereo- and compound microscopes. The material was deposited in the Department of Biology, Faculty of Arts and Sciences, Sinop University.

Physico-chemical features of sea water such as temperature, salinity, pH, dissolved oxygen concentration (DO), conductivity, total dissolved solids (TDS) and pressure were determined in the field using YSI 6600 V2 Water Quality Sonde.

Statistical Analysis

Community parameters such as number of species, number of individuals, Shannon–Wiener's diversity index (log2 base) (H′) and Pielou's evenness index (J′) were calculated for each station in each sampling period. The pooled abundance data of species, obtained per sampling station in each season, were analyzed using cluster techniques based on the Bray-Curtis similarity (Clarke & Warwick, 2001). Temporal variation in species composition and abundance at each station was analyzed using one-way analysis of variance. Prior to the analysis, data were tested for normality by the Kolmogorov–Smirnov test, whereas homogeneity of variance was tested with Cohran's C test. Canonical Correspondence Analysis (CCA) was performed to analyze the relationship between the polychaeta assemblages and environmental factors. Prior to the analysis, the raw data (number of individuals) were transformed using the log transformation [y = log(x + 1)]. Monte Carlo permutations were used to test the significance of the ordination axes. Diversity-evenness indexes and hierarchical clustering analysis were performed by using PRIMER 5, ANOVA and Kolmogorov-Smirnov were analyzed by using STATISTICA 7.0 and CCA was performed by using CANOCO 4.5.

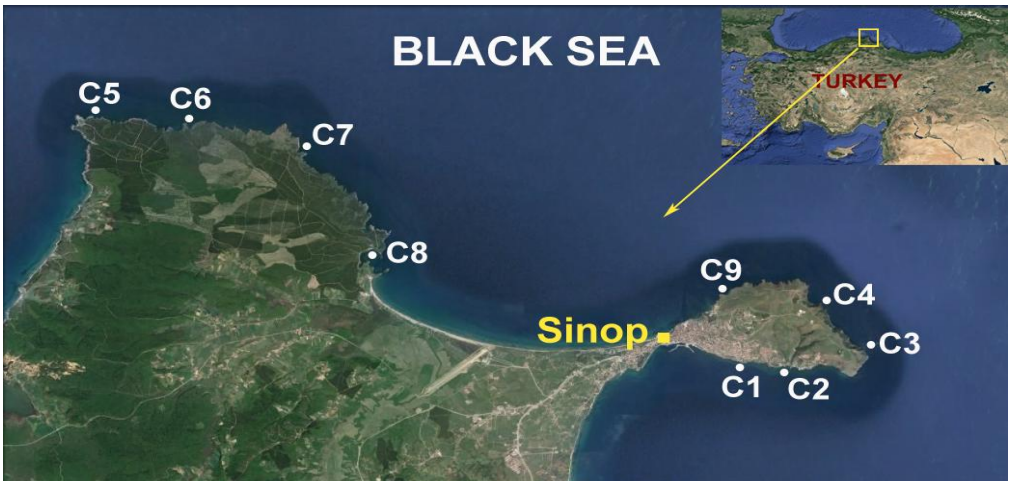

Figure 1. Map of the sampling stations.

Table 1. Sampling stations

Station	Coordinates	Depth (m)	Biotope
C1	42º01'05" N 35º10'00" E	2	*C. crinita*
C2	42º00'58" N 35º10'58" E	3	*C. crinita*
C3	42º01'18" N 35º12'55" E	4	*C. crinita*
C4	42º02'21" N 35º11'35" E	5	*C. crinita*
C5	42º05'47" N 34º56'60" E	4	*C. crinita*
C6	42º05'37" N 34º58'58" E	4	*C. barbata*
C7	42º05'06" N 35º01'18" E	5	*C. barbata*
C8	42º03'46" N 35º02'34" E	2	*C. crinita*
C9	42º02'16" N35º09'50" E	5	*C. crinita*

Results

Faunistic analysis of *Cystoseira* beds revealed a total of 39 polychaete species belonging to 17 families (Table 2), of *Sabellaria spinulosa* was a new record for the Turkish Black Sea coast. Among the families, Syllidae was the most representative family by 10 species followed by Phyllodocidae (4 species) and Serpulidae (4 species). The families represented by only one species were Pholoidae, Pilargidae, Nephtyidae, Paraonidae, Chaetopteridae, Cirratulidae, Opheliidae, Sabellariidae, Terebellidae and Sabellidae. *Cystoseira barbata* was sampled from station C6 and C7; while *C. crinita* from others. When comparing two algae species in terms of polychaete species composition, *Spirobranchus triqueter*, *Aricidea (Acmira) cerrutii* and *Spiochaetopterus* sp. were found on only *C. barbata*. It is considered that this finding could not be as a result of biotope preference and may be random as the species were determined only at station C6.

The most dominant species in the area were *Platynereis dumerilii* (28.3% of total number of individuals) and *Salvatoria clavata* (21.87%) followed by *Nereis zonata* (15.15%), *Heteromastus filiformis* (4.9%) and *Polyopthalmus pictus* (10.69%) based on all samples. The maximum density (9,700 ind.m^{-2}) of *S. clavata* was found at station C2 (spring); maximum density (7,200 ind.m^{-2}) of *P. dumerilii* was found at same station on summer season; maximum density (2,475 ind.m^{-2}) of *N. zonata* was determined at station C7 on summer; maximum density (5,475 ind.m^{-2}) of *P. pictus* was found at station C1 during autumn. The dominant species varied among seasons (Table 3). *Janua pagenstecheri, Neodexiospira pseudocorrugata* and *Pileolaria militaris* were also typical components of the *Cystoseira* facies in the Sinop Peninsula.

Seasonal variation in the mean number of species, the mean number of individuals, the mean diversity index value and the mean evenness index value are given in Figure 2. Statistically significant difference was found among seasons, in terms of the mean number of individuals and the mean number of species, the mean diversity and evenness index values ($P<0.05$). The number of species (400 cm^2) ranged from 1 (C3, autumn) to 15 (C1, spring) and the number of individuals (m^2) from 25 (C3, autumn) to 11,800 (C1, autumn). The mean number of species was high in spring and summer, low in winter (Figure 2). The seasonal variations in the mean number of individuals were statistically significant in station C5 and C7 ($P<0.05$). The maximum mean density was determined at station C1 in autumn (11,800 ind.m^{-2}) where *P. dumerilii* and *P. pictus* formed very dense population (max. density 6,575 ind.m^{-2} and 5,475 ind.m^{-2}, respectively) followed by station C8 in spring (11,500 ind.m^{-2}) where *S. clavata* was represented high density (max. density 5,625 ind.m^{-2}). The mean number of diversity value (H') ranged from 0.7 (C5, autumn) to 2.58 (C8, spring); the mean evenness index value (J') from 0.3 (C3, autumn) to 0.95 (C9, autumn). The highest diversity index value was calculated in spring at station C6 (Figure 2).

The association of polychaete species among *Cystoseira* beds is shown by the dendrogram in Figure 3. The average linkage shows the hierarchical cluster of species grouped into five associations. Group A (*Aricidea* (*Acmira*) *cerruti* and *Spiochaetopterus* sp.) showed an average similarity of 100%; Group B (*Syllis gracilis, Micronepthys stammeri* and *Sigambra tentaculata*) showed 57.83%; Group C (*Mysta picta* and *Harmothoe imbricata*) showed 66.67%; Group D showed (*Eumida sanguinea, Syllis prolifera, S. krohni, S. clavata, P. pictus, N. zonata* and *P. dumerillii*) showed 61.03%; Group E (*Nudisyllis rubiginosa* and *Exogone naidina*) showed 51.75%. *Heteromastus filiformis* did not belong to either of the groups (Figure 3).

The similarity of the stations was also very high (>65%) according to Bray-Curtis Similarity, because the composition of species were almost similar among stations. Two main groups were distinguished among the stations. First group (C4, C6, C7 and C9) linked together with a similarity level of 76%; second (C1, C2, C5 and C8) with a similarity of 70%. The station C3 joined second group with 65% similarity value.

The Canonical Correspondence Analysis (CCA) was carried out to determine which environmental factors influence the temporal and spatial distribution of Polychaeta species (Table 4). Ordination diagram of CCA is shown in Figure 4. The Monte Carlo test indicated that all canonical axes were statistically

Table 2. List of species identified during the study and their average densities (ind.m^{-2}) per station (F: Autumn, W: Winter, Sp: Spring, S: Summer, +: presence)

	C1				C2				C3				C4				C5				C6				C7				C8				C9			
	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S
Polynoidae																																				
Harmothoe imbricata (Linnaeus, 1767)						8																														
Harmothoe sp.			33	67			17						8				8	400	217			83	108		8	8	75		17		25			50	125
Pholoidae																																				
Pholoe inornata Johnston, 1839																		17		67	17	25				8		8	8				8			
Phyllodocidae																																				
Eumida sanguinea (Orsted, 1843)		25	17	42		17		17	17		8	17		25	42	50			33	50		17	42	42	100		8	275	25	25	8	42	8			42
Mysta picta (Quatrefages, 1865)						8												8																		
Nereiphylla rubiginosa (Saint-Joseph, 1888)	8								8				42				17				42		8	8	33											
Pterocirrus sp.				8																							8									92
Pilargidae																																				
Sigambra tentaculata (Treadwell, 1941)									8																											
Syllidae																																				
Exogone naidina Orsted, 1845			50		8	67	525	25					8	50			17	1650								200	8		17	258	8		17	92	
Myrianida edwarsi (Saint-Joseph, 1887)	50	50	8		25	8			58				33									8		83	8			17		17					
Nudisyllis pulligera (Krohn, 1852)			8				8											17								8	8			175	33		17		
Salvatoria clavata (Claparede, 1863)	142	1817	2833	433	242	1108	3908	492	92	192	283	8	50	67	158	125		100	583	33	17	33	492	8	17	100	533	533	25	175	2817	533		100	542	
Salvatoria limbata (Claparede, 1868)	58	200	383	58	75	233	442	67	17	25	42				75	17	8	158					117			25	133	117		25	792	25			75	
Salvatoria sp.		25		725	17	8		8	8							25		42	17				58					42			1092	2608				100
Syllis gracilis Grube, 1840									25	8																										
Syllis krohni Ehlers, 1864	25	58	33	8	25	25	42	8	17	25	8	17	183	25	75	8	8		8	33	92	8	58		133	25	17	142	33	17	50	42		50	17	100
Syllis prolifera Krohn, 1852	8							33	42	17	233	158	208	58	158	42			8		33			50	142	33	8	250	58	8	42		25	75	33	192
Syllis sp.												8			33								17							8						8
Nereididae																																				
Nereis zonata Malmgren, 1867	517	408	408	675	233	58	175	308	567	483	242	200	775	242	283	183	133	25	33	83	350	33	100	117	825	367	175	1925	492	283	400	375	50	342	167	842
Perinereis cultrifera (Grube, 1840)			8	517				17								25					17			8			17		8		8		8		25
Platynereis dumerilli (Audouin & Milne Edwards, 1833)	3075	392	383	2342	2275	167	667	4275	125	58	25	92	558	600	175	1475	717	67	658	317	225	17	125	50	392	283	225	675	933	342	483	1433	33	92	183	117
Nephtyidae																																				
Micronephtys stammeri (Augener, 1932)									8																											
Spionidae																																				
Polydora sp.																			8																	
Prionospio cirrifera Wiren, 1883										8												8				17										
Prionospio maciolakae Dagli & Cinar, 2011	17								8	17											8								8							
Paraonidae																																				
Aricidea (*Acmira*) *cerruti* Laubier, 1967																					8															
Spiochaetopteridae																																				
Spiochaetopterus sp.																					8															
Cirratulidae																																				
Cirriformia cf. *tentaculata* (Montagu, 1808)															8																					
Opheliidae																																				
Polyophthalmus pictus (Dujardin, 1839)	2317	1275	392	667	275	167	425	458	33	58	33		358	75	42	133	8		33		250	58	117		167	33	175	58	133	208	717	200	25	33	133	25
Capitellidae																																				
Capitella teleta Blake, Grassle, Eckelbarger, 2009	58			8	25																								8						
Capitella sp.			92		8		8	17																8												
Heteromastus filiformis (Claparede, 1864)		8																																		
Sabellaridae																																				
Sabellaria spinulosa (Leuckart, 1849)								8																												
Terebellidae																																				
Polycirrus sp.			8																	8			8	8	17				17	8	8			17	8	8
Sabellidae																																				
Fabricia stellaris adriatica (Banse, 1956)	108																	17																		
Serpulidae																																				
Spirobranchus triqueter (Linnaeus, 1758)																								8												
Janua pagenstecheri (Quatrefages, 1865)	+	+	+	+	+		+	+			+		+	+	+	+		+		+	+	+		+	+	+		+	+	+	+		+	+	+	+
Neodexiospira pseudocorrugata (Bush, 1905)	+	+	+	+	+	+	+	+	+		+		+	+	+	+	+	+	+	+		+		+	+	+	+	+	+	+	+		+	+	+
Pileolaria militaris (Claparede, 1870)	+	+	+	+	+	+	+	+									+	+	+	+						+	+			+	+	+				

Table 3. The percentage total abundance of dominant species among seasons

	Autumn	Winter	Spring	Summer
Exogone naidina	0.04	1.06	10.19	0.16
Platynereis dumerilii	43.92	17.18	10.55	40.60
Nereis zonata	20.77	19.09	7.15	17.70
Polyopthalmus pictus	18.80	16.25	7.45	5.81
Salvatoria clavata	3.07	31.44	43.81	8.16
Salvatoria limbata	0.79	4.40	7.99	1.07
Salvatoria sp.	0.13	0.28	4.30	13.30

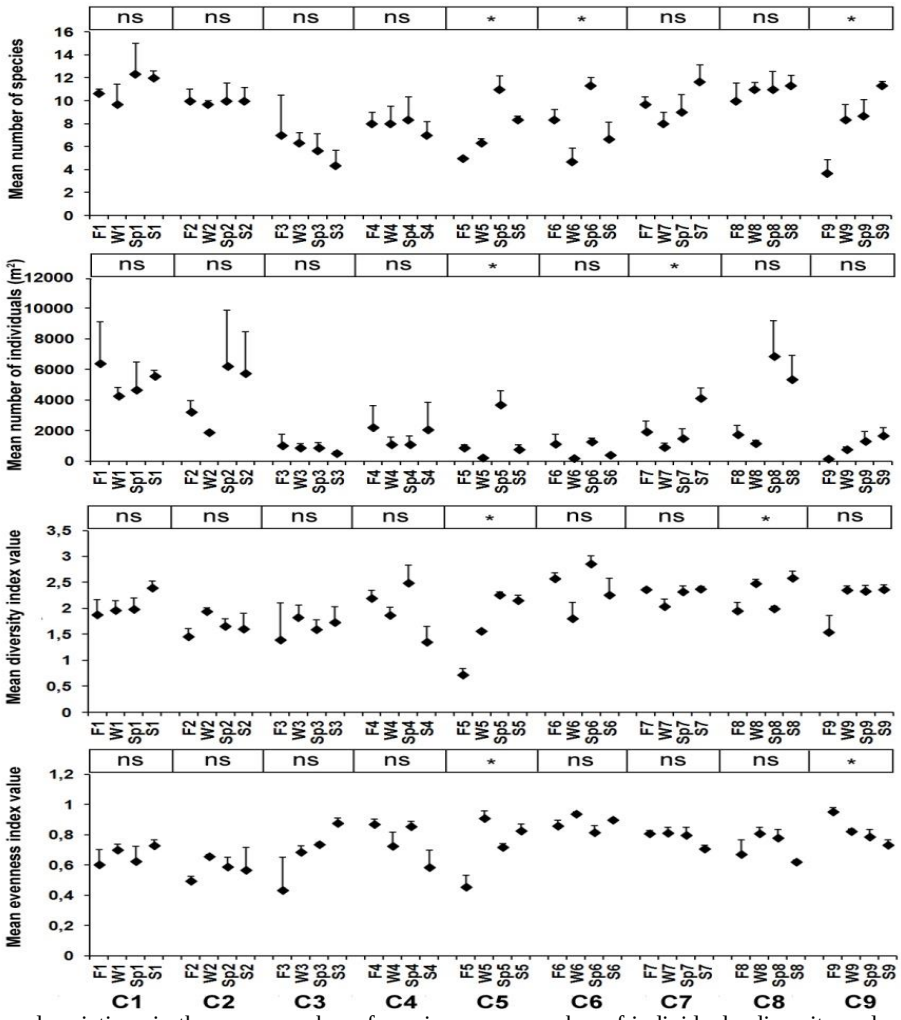

Figure 2. Temporal variations in the mean number of species, mean number of individuals, diversity and evenness index values ± standard error (F: Autumn, W: Winter, Sp: Spring, S: Summer; *: Statistically significant ($P < 0.05$), ns: not significant).

significant (F= 1.96, P= 0.002). The CCA axes 1 and 2 explained 14.4% and 23.1% of the species variation and 39.0% and 62.9% of the species-environment variation, respectively. All four CCA axes showed high values of species environment correlation (r= 0.905, 0.859, 0.716 and 0.732 for axis 1 to 4). According to CCA, there was a strong correlation between physicochemical variables and polychaete communities (Table 4). The main factors affecting polychaete community were temperature, dissolved oxygen value and salinity according to CCA analysis (r= 0.76; r= 0.75; r= -0.61, respectively). CCA analysis showed that temporal variation was more effective than spatial changes on the polychaete community structure.

Discussion

Among 39 polychaete species associated with *Cystoseira barbata* and *C. crinita*, the most dominant and frequent species were *Salvatoria clavata*, *Platynereis dumerilii*, *Nereis zonata* and

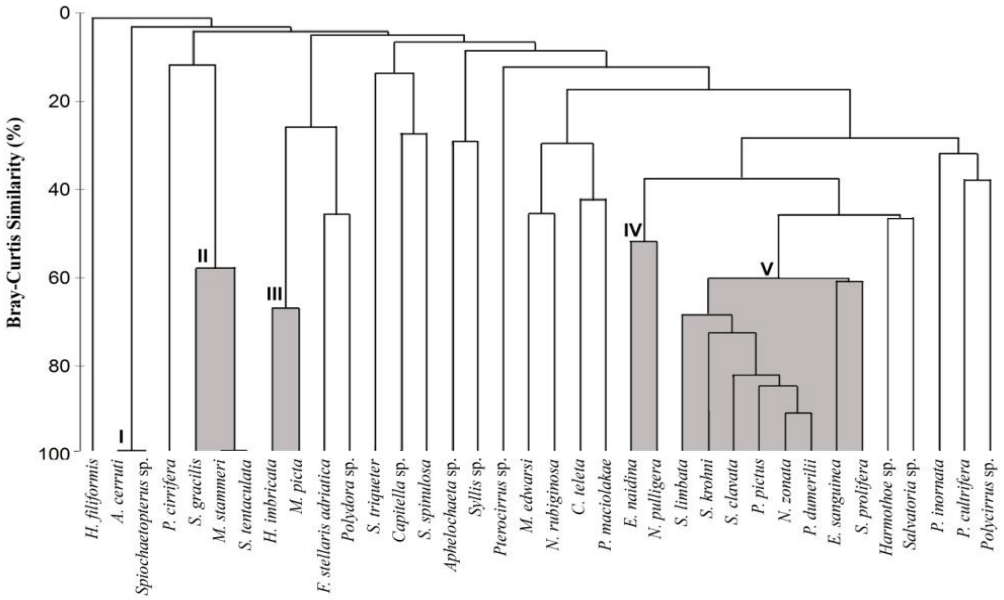

Figure 3. Dendrogram of species association.

Table 4. Results of canonical correspondence analysis

Environmental variables	Axis 1	Axis 2
Depth	**-0.401**	**-0.494**
Temperature	-0.087	**0.758**
Salinity	**-0.432**	**-0.616**
pH	0.351	**0.527**
Conductivity	0.377	**0.547**
Total Dissolved Solid (TDS)	-0.382	**-0.552**
Dissolved Oxygen (DO)	**-0.424**	**0.750**
Pressure	0.040	**0.498**
Eigenvalues	0.131	0.080
Species-environment correlations	0.905	0.859
Cumulative percentage variance of species data	14.4	23.1
Cumulative percentage variance of species-environment relation	39.0	62.9

Polyophthalmus pictus based on all samples. The characteristic species of *Cystoseira* facies in the present study were same for the other studies focused on same facies in the different areas (Alós, 1990; Ergen and Çinar, 1994; Fraschetti *et al.*, 2002; Çinar and Gonlugur-Demirci, 2005; Gozler *et al.*, 2010).

The main factors affecting polychaete community were temperature, dissolved oxygen value and salinity in the area. As no detailed previous study on correlation between environmental variables and polychaete community of *Cystoseira* facies is available in the Turkish Black Sea coast, the results of the present study could not be compared with any other studies. Çinar *et al*. (2008) reported that *Cystoseira* facies distributed along the Levantine Sea of Turkey have the maximum value (H'=4.03) of the mean diversity index and evenness index (J'=0.71) among macro algae in the area. The mean diversity and evenness index value of the present study were low. It could be connected to the typically low biodiversity in the Black Sea than Mediterranean. The same authors also notified that temperature, ammonium, dissolved oxygen and salinity were the major factors affected to *Cystoseira* facies. These results are parallel to our findings.

Polychaeta assemblages associated with *Cystoseira* facies were examined by few numbers of studies in Turkish coasts (Ergen and Çinar, 1994; Çinar and Gonlugur-Demirci, 2005; Gozler *et al.*, 2009). Ergen and Çinar (1994) reported 58 polychaete species from 5 stations in the Aegean Sea and pointed out that *P. pictus*, *N. zonata* and *P. dumerilii* were the most frequent (90-100%) species. Çinar and Gonlugur-Demirci (2005) recorded 55 polychaete species of which 31 species were found on *C. barbata* in the Sinop Peninsula and reported that *P. dumerilii, N. zonata* and *S. clavata* were the most dominant species in all seasons. Gozler *et al.* (2009) examined

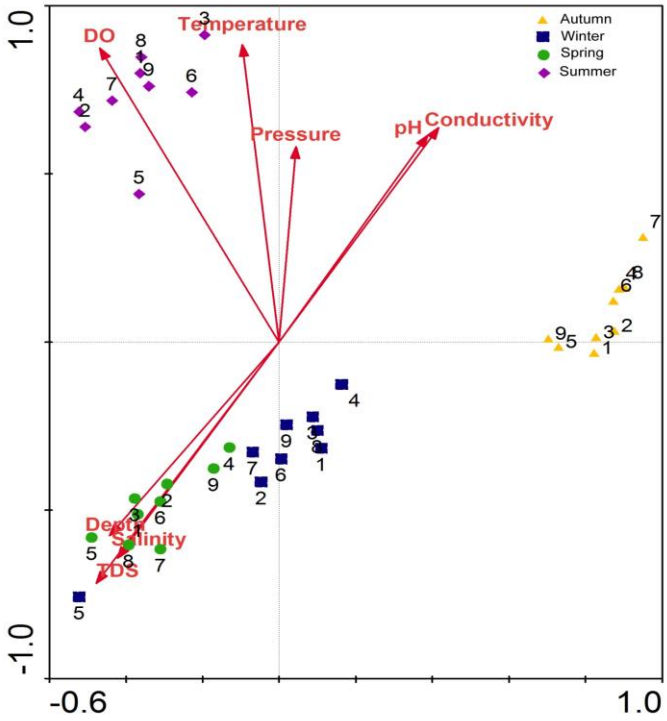

Figure 4. Biplot of CCA performed on total abundance of species and environmental variables in the study area (DO: Dissolved oxygen, TDS: Total dissolved solid).

Nereididae species associated with *Mytilaster lineatus* and *C. barbata*. They found 6 nereidid species at four stations in the eastern Black Sea coast of Turkey of which *P. dumerilii* and *N. zonata* were the most dominant and frequent species.

Çinar and Gonlugur-Demirci (2005) noticed that the most diverse facies was *C. barbata*, than others (*M. galloprovincialis* and *U. rigida*) and they reported that the most contributed species were *Exogone naidina* (max. 15,875 ind.m^{-2}), *S. clavata* (max. 20,550 ind.m^{-2}), *Nudisyllis pulligera* (max. 10,625 ind.m^{-2}) and *P. dumerilii* (max. 17,000 ind.m^{-2}). Milovidova (1966), Tiganus (1972) and Andriescu (1977) examined macrozoobenthic invertebrates associated with *Cystoseira* in the Black Sea. Milovidova (1966) recorded 14 polychaete species on *C. barbata* and noticed that *N. zonata*, *P. dumerilii* and *Spirobranchus triqueter* were characteristic species for community. Andriescu (1977) reported that *P. dumerilii* was densely occurred on *Cystoseira* beds. According to the studies carried out in the Mediterranean Sea, Polychaeta diversity was higher on *Cystoseira* beds in the Mediterranean than the Black Sea. Çinar (2003) found 53 syllid species on *C. crinita* and *C. compressa* facies (50 and 6 species, respectively). Alós (1990) reported 86 species on *C. mediterranea* from the western Mediterranean. Çinar *et al*. (2008) identified 101 polychaete species on *C. crinita* and *C. elegans* from the Levantine Sea coast of Turkey. The most frequent species were *P. pictus* (100%), *Branchiosyllis exilis* (100%), *N. zonata* (95%), *Amphiglena mediterranea* (86%) and *Pseudonereis anomala* (81%). Lessepsian migrant *P. anomala* was also the most dominant species (max. 9,750 ind.m^{-2}) on the area. While the dominant species of *Cystoseira* facies in the Mediterranean were *P. dumerilii*, *S. clavata* and *Syllis prolifera*; *P. dumerilii* and *S. clavata* were in the Black Sea, *S. prolifera* was occurred rarely. However, unlike species composition of the Mediterranean, *E. naidina* and *N. pulligera* were densely occurred in the Turkish coast of the Black Sea (Çinar and Gonlugur-Demirci, 2005). Our findings are parallel to Çinar and Gonlugur-Demirci (2005).

The present paper provided detailed examination of temporal dynamics of Polychaeta assemblages associated with *C. barbata* and *C. crinita* around the Sinop Peninsula and determined the environmental factors in the community and their seasonal dynamics. Future studies to be undertaken along the Turkish Black Sea coast would enable to revealed latest status of *Cystoseira* beds and their community patterns.

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