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Temporal Variations of the Demersal Fish Community in the Shallow Waters of Çanakkale Strait, North Aegean Sea, during the Course of a Mucilage Event

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Abstract

The main aim of this study was to determine the mucilage event effect on the temporal variations of the shallow water demersal fish community in the Çanakkale Strait. Sixty-one different demersal fish species were collected with a beach seine between September 2006 and August 2009. Mucilage event was observed between September 2007 and July 2008 (mucilage period) in the shallow waters of Çanakkale Strait. Species abundance and richness decreased in winter and increased in spring and in summer and was related to water temperature variations. Demersal fish species composition was significantly different between seasons but these differences were mainly related to water temperature variations. For the same seasons in different years (pre-mucilage, during mucilage, and post-mucilage), no differences of fish abundance and species richness were evident. In conclusion, the fish community data from our shallow water samplings during the course of a mucilage event does not suggest any significant change in the abundance and species richness of the shallow water demersal fish assemblage in Çanakkale Strait.

Keywords: Mucilage, species richness, demersal fish fauna, Aegean Sea.

Kuzey Ege Denizi Çanakkale Boğazı Sığ Sularındaki Müsalaj Olayı Esnasında Demersal Balık Topluluğunun Zamansal Değişimi

Özet

Bu çalışmanın ana amacı, Çanakkale Boğazındaki sığ su demersal balık topluluğunun zamansal değişime müsilaj olayının etkisini belirlemektir. Eylül 2006 ile Ağustos 2009 yılları arasında ığrıp ile 61 bir farklı demersal balık türü toplanmıştır. Çanakkale sığ sularında musilaj olayı Eylül 2007 ile Temmuz 2008 (müsilaj periyodu) arasında gözlemlenmiştir. Tür bolluğu ve çeşitliliği sıcaklık değişimleri ile ilişkili olarak kış aylarında düşüş göstermekte, bahar ve yaz aylarında ise artış göstermektedir. Mevsimler arasında demersal balık türlerinin kompozisyonu önemli derecede farklılık göstermektedir. Fakat bu farklılık temelde su sıcaklığı değişimleri ile ilişkilidir. Farklı yıllardaki aynı mevsimlerdeki (musilaj öncesi, musilaj esnası ve musilaj sonrası) balık bolluğu ve çeşitliliğinde farklılık olmadığı tespit edilmiştir. Sonuç olarak, musilaj olayı sırasında sığ su örneklemelerimizden elde edilen balık topluluğu verileri Çanakkale Boğazı sığ sularındaki demersal balık topluluklarının tür zenginliği ve bolluğunda önemli bir değişiklik olmadığını göstermektedir.

Anahtar Kelimeler: Müsilaj, tür zenginliği, demersal balık faunası, Ege Denizi.

Introduction

Mucilage has been defined as the biogeochemical formation of aggregated mucus-like organic matter in the marine environment (Azam *et al.*, 1999). The gelatinous mucilage formation has been reported to be produced by a slow-to-degrade organic matter that is generated by an uncoupling between the organic carbon production and the consumption (Fonda Umani *et al.*, 2007). Based on the typology, size and spatial distribution, the mucilage formation has been classified as macroflocs, stringers, clouds, creamy surface layer, gelatinous surface layer, flocs, ribbons, cobweb, false bottom, and blanket (Precali *et al.*, 2005; Stachowitsch *et al.*, 1990).

The mucilage formation has been reported to have adverse ecological effects on the marine life. Stachowitsch (1984) reported a mass mortality of the macroepifauna community due to anoxic conditions caused by mucus-like matter in the Gulf of Trieste. Mucilage covered seagrass beds and caused the death of many benthic organisms including demersal fish species in the Bay of Piran (Stachowitsch *et al.*, 1990). The number of species and the densities of all macrobenthic taxa were simultaneously reduced by the foam, resulting from the release of mucilaginous polysaccharides accumulations, in the shallow waters of the eastern English Channel (Desroy and Denis, 2004). Mucilage caused different types of damage to the different gorgonian species in the Tyrrhenian sea (Giuliani *et al.*, 2005). Sedimentation of the mucilaginous material was responsible for the mortality of benthic organisms such as mollusca, coelenterates and crustaceans (Rinaldi *et al.*, 1995).

The first mucilage event reported dates back to1729 with many mucilage events between 1873 and 2004 in the Adriatic Sea (Precali *et al.*, 2005). In the Tyrrhenian Sea the mucilaginous aggregates was observed in 1991, 1993, and 2000 (Lorenti *et al.*, 2005). In the summer of 2003 mucilage aggregation was observed in the Ligurian Sea (Schiaparelli *et al.*, 2007). Gotsis-Skretas (1995) reported 23 mucilage events between 1982 and 1994 from the Greek waters. Mucilage aggregation in Turkey was initially observed as creamy and gelatinous surface layers in fall 2007 and then accumulated and covered the sea bottom over hundreds of kilometer squares in the Bosporus, Marmara Sea, Çanakkale Straits, and northern Aegean Sea with irregular spatial and temporal patterns until July 2008 (Aktan *et al.*, 2008; Balkis *et al.*, 2011; Tufekci *et al.*, 2010).

The mucilage aggregation in the Çanakkale Strait accumulated in denser masses in shallow bays with relatively lower current speed. Shallow marine ecosystems support a great abundance and diversity of fish that serve mainly as nurseries (Beck *et al.*, 2001) and are extremely vulnerable to disturbances (Thedinga *et al.*, 2013).The main aim of this study was to determine the mucilage event effect on the temporal variations of the shallow water demersal fish community structure in the Çanakkale Strait.

Materials and Methods

This study was carried out in a relatively shallow bay (< 2 m) at Güzelyalı (26°20′16″ E – 40° 02′ 22″ N) in the Çanakkale Strait (Figure 1). The Çanakkale strait has a 62 km long coastline and a mean depth of 55 m. The strait is a conduit for low salinity and relatively cold waters originating from the Black Sea flow into the Aegean Sea at the upper-layer current. It is also a partway for high salinity water and relatively warm waters move from the Aegean Sea to the Sea of Marmara at the lower-layer (Beşiktepe *et al.*, 1993; Bianchi, 2007).

Fish samples were collected monthly with a beach seine between September 2006 and August 2009. The beach seine had a total wing length of 32 m and a height of 2 m with 13 mm mesh size; the central collection bag was 2 m long with 5 mm mesh size. Two consecutive hauls with at least 100 m distance

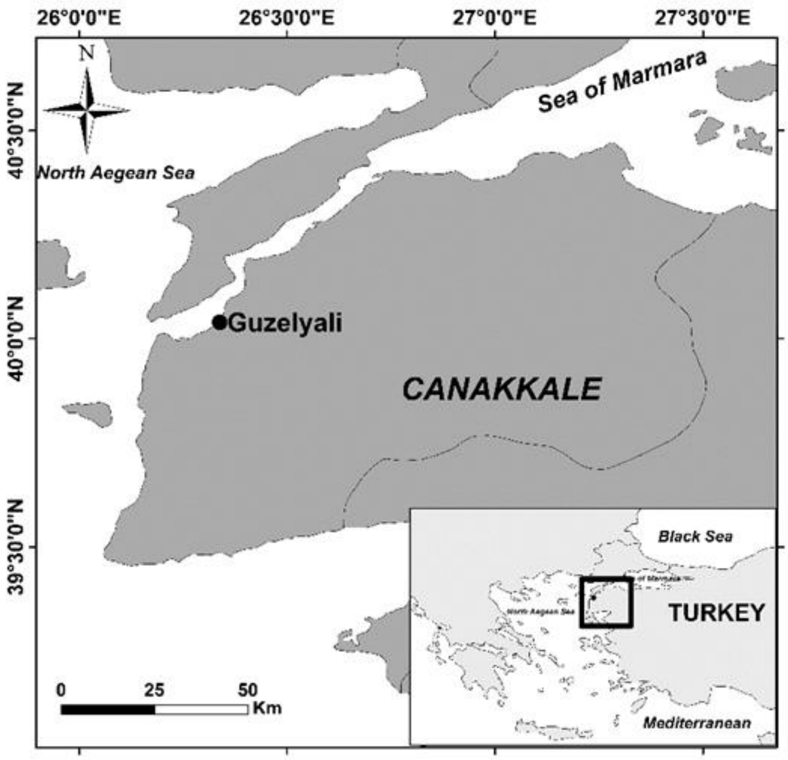

Figure 1. Sampling station in the Çanakkale Strait.

and 30 min apart were made with the seine parallel to the shore.

Fish were killed in a water filled bucket with an overdose of quinaldine and were fixed in 4% formaldehyde for laboratory works. Fish were identified with the species keys provided in Whitehead *et al*. (1986) and in Mater and Çoker (2004).

Shannon index (*H*) was used to characterize species diversity in the community using the following equation:

$$H = -\sum_{i=1}^{S} (p_i)(\ln p_i)$$

where *S*is the number of taxa, p_i is the proportion of individuals found in the *i*'th species (Shannon and Weaver, 1949).

Dominance index (*D*) was used to explore taxon evenness using the following equation:

$$D = \sum_{i=1}^{S} (p_i)^2$$

Catch per unit effort (CPUE) was calculated by the total number of each species per beach seine haul and were log transformed. Local temperatures were obtained from the Turkish State Meteorological Service. Nonmetric Multidimensional Scaling (NMDS) analysis was carried out to associate fish abundance with months and years. For the "season" factor, December, January and February represented winter, March April and May represented spring, June, July and August represented summer, and September, October and November represented fall. Analysis of similarities (ANOSIM) and similarity percentage tests (SIMPER) were executed with seasonal amounts of the species.

Analysis of variance (ANOVA) was used to compare seasonal abundance before, during and after the mucilage occurrence.The relationship between temperature and species richness were determined using Pearson correlation coefficient.

Statistical analyses were performed with the software PAST version 3.04 (Hammer *et al.*, 2001). Statistical significance level was accepted as $\alpha = 0.05$.

Results

A total of 17583 individuals belonging to 68 species caught with beach seine from Çanakkale shallow waters between September 2006 and August 2009.Sixty-one of these species were demersal fish. The most abundant species were *Atherina boyeri*, *Pomatoschistus marmoratus* and *Chelon labrasus* (Table 1). The mucilage aggregation was observed intensively between September 2007 and July 2008 in Çanakkale shallow waters. The Shannon index (*H*) ranged between 0.43 and 2.58 throughout sampling period. The lowest *H* value was observed in winter 2007 (before the mucilage period). The dominance index (*D*) reached its highest value (0.852) in the same season (Figure 2). The highest CPUE of *A. boyeri* (211.33) was observed in spring 2007 (before the mucilage period) whereas the lowest CPUE (1.33) was in spring 2008 (during the mucilage period).In contrast, abundance of *C. labrasus* increased during and after the mucilage period. Moreover, the abundance of *P. marmoratus* did not show a decrease during and after the mucilage periods (Table 1).

Demersal fish species composition were significantly different between seasons (ANOSIM; Global-R = 0.58, P<0.05). The results of SIMPER analysis indicated that differences between seasons was mainly due to the variations of the dominant species *A. boyeri* (Contribution=27.97), *Diplodus vulgaris* (Contribution=16.93) and *Mullussur muletus* (Contribution=10.76) (Table 2).

Species abundances and richnesses regularly decreased in winter and increased in spring and summer as did the temperature (Figure 2). Significant positive correlation was found between species richness and temperature (Table 3). CPUE values between the same seasons in different years (i.e. before, during, and after the mucilage period) were not significantly different (ANOVA; P<0.05). Similarly, non-metric multidimensional scaling (NMDS) showed that the ordination of the monthly abundances were similar within seasons even for different years (Figure 3).

Discussion

Numerous studies showed that mucilage events had negative effects on fish populations. Taylor *et al.* (1985) reported that bony fishes caught by longlines died because of the mucilage accumulation in the gills after the diatomeae *Cerataulina pelagica* explosion in the area. Kent *et al*. (1995) stated diatomeae explosions caused lesions on gills and even death for the Atlantic salmon *Salmo salar*. The catches of Italian anchovy, *Engraulis encrasicolus* significantly decreased because of the diatomeae explosions in northern and southern shores of the Adriatic Sea between 1986 and 1989 (Regner, 1996). The mucilage aggregation caused coating of various benthic organisms, including fish in Italian shores of the Adriatic Sea in 1989 (Stachowitsch *et al.*, 1990).

Based on the classifications provided by Stachowitsch *et al.* (1990) and Precali *et al.* (2005), the mucilage formations in the Çanakkale shallow waters was identified as creamy surface layer and especially blanket type mucilage. Blanket type mucilage can cause a decrease of the amount of the food in the bottom or prevented the food intake in the benthic living by covering the benthic habitat and causing anoxic conditions. Since demersal fish species rely on benthic prey as food sources, they are obliged to migrate towards sites characterized by high

Table 1. CPUE of fish species collected by beach seine in Çanakkale Strait (0-2 m) from September 2006 to August 2009

	2006	2007				2008				2009		
Species	Fall	Win	Spr.	Sum.	Fall	Win.	Spr.	Sum.	Fall	Win.	Spr.	Sum.
Aidablennius sphynx	0.00	0.25	0.00	0.00								
Apletodondentatus bacescui				0.17								
Arnoglossus kessleri					0.50			4.00	1.40	0.67		0.33
Atherina boyeri	87.00	190.50	211.33	119.50	30.17	21.00	1.33	9.00	24.80	3.00	16.83	86.50
Buglossidium luteum									0.20	0.67		
Calliony muslyra							0.33				0.50	
Calliony muspusillus				0.33		0.17		0.25				
Calliony musrisso								0.25	1.20	0.17	0.67	0.17
Chelidonichthys lucerna			0.33								0.17	
Chelon labrosus			0.83	6.33	0.83	2.83	3.00	23.75	11.00	2.50	18.67	5.50
Clinitrachus argentatus			0.33	0.17	0.83		1.00	0.25	1.40	0.33		0.33
Dentex dentex				1.33					0.20			
Dicentrarchus labrax	2.33	2.75	0.17	1.17	0.17			0.75	1.60			0.17
Diplodus annularis			11.17	25.50	5.50	0.17		8.75	3.40		0.67	5.33
Diplodus puntazzo	0.67		1.17			0.33		1.25	0.80	2.67	5.50	1.50
Diplodus sargussargus			5.00	0.50				11.25	0.40			
Diplodus vulgaris	0.67		1	38.17	2.67			18.00	1.40	0.50	372.83	302.83
Echiichthys vipera							0.33					
Gaidropsarus mediterraneus			1.00									
Gobius cobitis							0.33					
Gobius niger					0.17				0.40			
Gobius paganellus				0.17	1.17							
Labrus viridis				2.83	1.50			0.25				
Lithognathus mormyrus	27.00			1.83	1.00		0.67	1.50	1.00			
Liza ramado		0.50	0.50	3.17	0.17							
Liza saliens			0.17									
Mullus surmuletus	10.67			35.33	28.50			96.75	15.40			86.50
Nerophis ophidion		1.50	3.67	1.00	0.50	0.67	0.67		1.60	1.50	2.33	
Oblada melanura				0.33								
Pagellus acarne			5.83					0.25				
Pagellus erythrinus	0.33											
Parablennius gattorugine					0.33							
Parablennius sanguinolentus				1.00								
Parablennius tentacularis					0.33			0.75	0.20	0.17	0.17	
Pegusa lascaris		0.50			1.17	0.33		1.75		0.33		
Pomatoschistus bathi			0.33	0.33				0.25				0.83
Pomatoschistus marmoratus	7.33	4.75	13.50	8.67	9.00	4.50	5.67	8.00	6.60	8.33	5.67	2.17
Pomatoschistus pictus			0.83									
Psetta maxima		0.25						1.00	0.40			
Raja clavata										0.17		
Raja radula						0.17						
Salaria pavo					0.67			0.25				
Sarpa salpa				13.50				39.25	5.20		301.67	129.00
Sciaena umbra	0.33							0.25				
Scorpaena porcus	0.33		2.00	1.00	0.33	0.50	0.33	3.00	1.20		0.67	0.83
Sole asolea	0.33			0.67	0.33		0.33	1.75	0.60			0.33
Sparus aurata	0.33		0.33	0.83				0.50	0.20		4.33	0.17
Spondylios omacantharus				2.67								
Sprattus sprattus			1.17									
Symphoduscinereus	5.33	2.00	4.33	6.33	18.50	5.50	1.00	7.75	16.20	1.17	3.00	2.50
Symphodusocellatus	29.33	0.50	6.33	10.67	6.00	5.00	11.67	13.00	5.20	0.50	7.67	1.67
Symphodusroissali			1.33	23.17	34.17	4.50	0.33	23.25	1.20		6.00	2.50
Symphodusrostratus								0.25				5.83
Symphodustinca	2.00		0.17	4.50	0.50	9.67	1.33	3.00	0.60		0.17	3.83
Synapturichthyskleinii											0.50	
Syngnathus abaster			0.17	1.50	2.17	1.83	1.00	1.00	5.00	1.00	1.00	1.17
Syngnathus acus	5.00	2.00	6.00	1.17								
Syngnathus typhle		1.00	1.33	5.50	1.83	0.83		0.75	1.40	0.17	1.17	0.17
Trachurus trachurus			0.33									
Umbrina cirrosa				0.83	0.50				0.80			1.17
Zosterisessor ophiocephalus					0.17							

biomass of foods if they cannot find food on at the sites they currently inhabit. Consequently, a significant decrease in both abundance and richness of demersal fish species should be expected during a mucilage event due to mortality caused directly by mucilage clogging the gills and indirectly by the decreased food availability that may also force emigration from the affected area.

Mucilage formation arises from alternation of environmental factors, possibly caused by

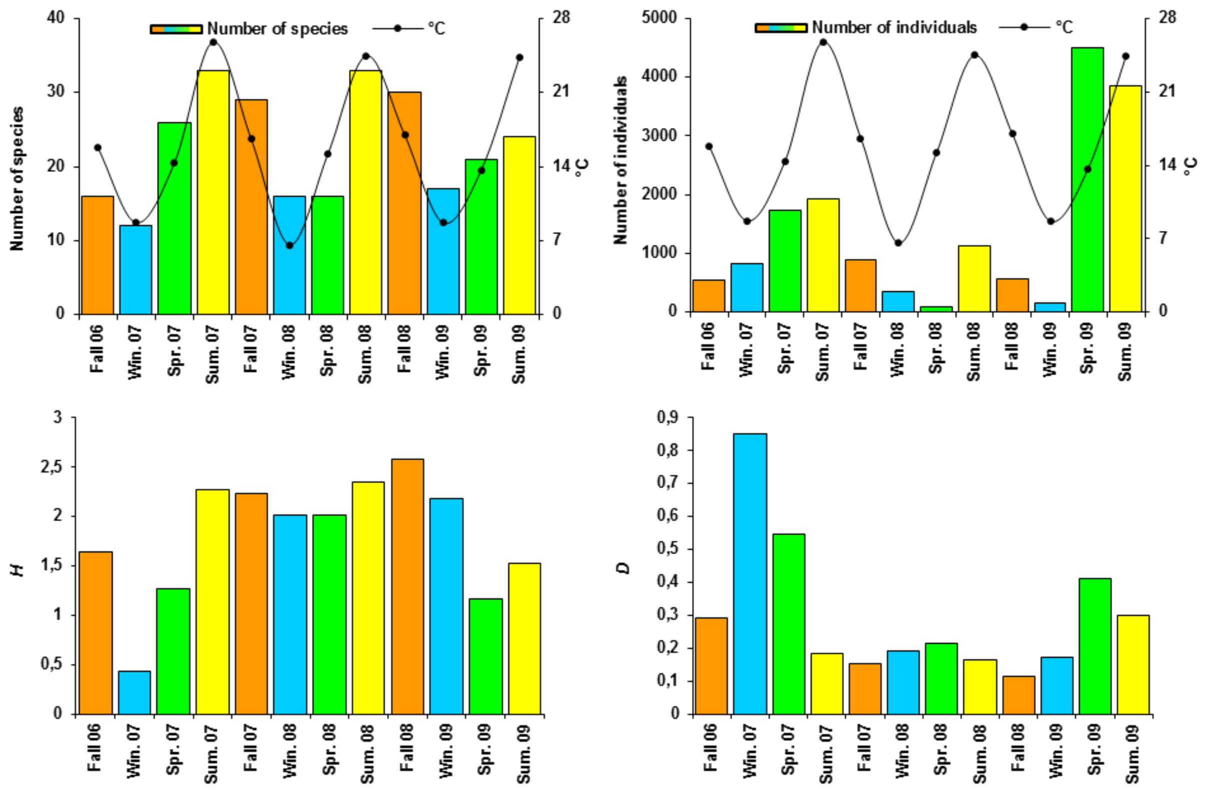

Figure 2. Number of species and number of individuals with temperature were sampled in Çanakkale Strait (0-2 m) from September 2006 to August 2009.Shannon (*H*) and Dominance (*D*) index values that were estimated from species number and abundance.

Table 2. SIMPER: fish species contributing most, in percentage, to the dissimilarity between seasons in the Canakkale Strait from September 2006 to August 2009

Taxon	Av. dissim	Contrib. %	Cumulative %
Atherina boyeri	21.96	27.97	27.97
Diplodus vulgaris	13.29	16.93	44.9
Mullussur muletus	8.449	10.76	55.66
Sarpa salpa	8.357	10.64	66.3
Symphodus roissali	4.141	5.275	71.58
Symphodus ocellatus	2.87	3.655	75.23
Symphodus cinereus	2.703	3.443	78.68
Pomatoschistus marmoratus	2.451	3.122	81.8
Chelon labrosus	2.23	2.841	84.64

Table 3. Pearson correlation coefficients between CPUE, species number, and temperature from shallow water of Canakkale Straitfrom September 2006 to August 2009

		CPUE	TEMP.	SPEC.
CPUE	PearsonCorrelation	1	.350*	0.24
	Sig. (2-tailed)		0.046	0.179
	N	33	33	33
TEMP.	PearsonCorrelation	.350*	1	.726**
	Sig. (2-tailed)	0.046		0
	N	33	36	33
SPEC.	PearsonCorrelation	0.24	.726**	1
	Sig. (2-tailed)	0.179	0	
	N	33	33	33

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

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

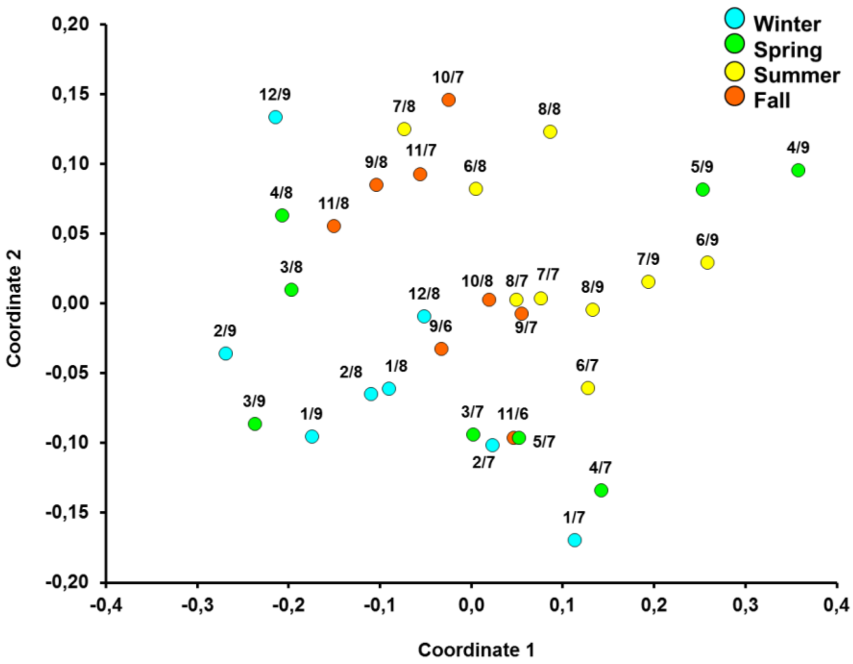

Figure 3. Monthly Nonmetric Multidimensional Scaling (NMDS) analysis results between September 2006 and August 2009 in Çanakkale Strait (0-2 m). The numbers on the points are the last digit of months and years (month/year).

environmental stress (Rinaldi *et al.*, 1995). Increasing levels of environmental stress have been considered to decrease diversity (*H*) and increase dominance (*D*) in the marine ecosystem (Clarke and Warwick, 2001). In this study, the lowest *H* and the highest *D* values were observed in winter 2007 that corresponded to pre-mucilage period. Abundance and species richness was significantly different between seasons, but these differences were mainly related to water temperature variations. No differences of abundance and species richness were observed for the same seasons in different years, indicating that there was no significant negative mucilage effect on the demersal fish fauna in the Çanakkale Strait.

The magnitude of the mucilage effect on the benthic ecosystem is related to the seafloor morphology and the hydro dynamical conditions; waves and currents are sufficient to scatter the mucilage in sandy shallow waters (Devescovi and Ivesa, 2007). Destroy and Denis (2004) reported that the post-mucilage renewal process of living organisms in sandy areas are quicker than muddy areas. The strong currents in the Çanakkale Strait along with the sandy bottom structure in the study area were possibly the reasons that no significant effect of mucilage on the demersal fish assemblage was observed.

In conclusion, the fish community data from our shallow water samplings during the course of a mucilage event does not suggest any significant change in the abundance and species richness of the shallow water demersal fish assemblage in Çanakkale Strait. The effect of mucilage may have been mitigated by the strong currents at the sandy shallow waters. However, further investigations should focus on the effects of mucilage on demersal fish assemblages in different habitat types with different hydrological conditions.

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