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Influences of different collector materials on Mediterranean mussel, *Mytilus galloprovincialis* L. 1819 in the Dardanelles.

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ABSTRACT

The present study is carried out in Kilya Bay (in the Dardanelles) between February 2002 and February 2004. The purpose of this study was to determine the most suitable collector material, time to collect mussel seed, and the growth rate. In the first three months of the study, different collector materials (net rope, polypropylene rope, sisal rope, and jute rope) were deployed in the water column. Spat recruitment was not varied between collector materials ($p>0.05$). When resistance of ropes were compared against the effects of water, it was found that net rope was most suitable for the mussel seed collection. Net collectors were deployed in February, March, April, May, June, and January. Mussel spat settlement was observed throughout the study, however between collectors, spat attachment was significantly different between months ($p<0.05$). The higher attachment period was observed in February and April. These results showed that mussel reproduction period was all year round and first attachment individuals reached marketable (<50 mm) size in 1.5 year.

Introduction

The Mediterranean mussel, *Mytilus galloprovincialis* Lamarck, 1819 has dense populations in the Black Sea, the Sea of Marmara, and the northern Aegean Sea (Uysal, 1970). Recently, mussel production is generally performed through catching, and culture attempts. To obtain enough spat from the natural environment is vital for the mussel culturing. Hatchery is extensively performed in China and Tahiti for obtaining the spats (Gosling, 1992). The spats in the regions cited are usually obtained directly from the nature or they are gathered by means of the collectors (Korringa, 1976; Fuentes et al., 1998). Lekang et. al (2003) indicated that since attachment and growth performances of mussels rise under convenient circumstances, the collector material to be used is greatly significant for collecting more mussel seeds. The appropriate residential areas for the mussel seeds are the surfaces of rugged filaments (Dare et al., 1983; Caceres-Martinez et al., 1994; Lök, 2000). Growth rates of mussels are dependent on tidal level, the wave exposure, population density, salinity, and especially the temperature and amount of food in the water (Eldridge et al., 1979; Sukhotin and Maximovich, 1994).

The main goals of this study are to compare the resistance of different collector models in the sea water, determine reproduction seasons and the peak season for mussel seeds attachment, and monitor the growth of settled mussels.

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Material and methods

The present study is carried out in Kilya Inlet (the Dardanelles) between February 2002 and February 2004

(Figure 1).

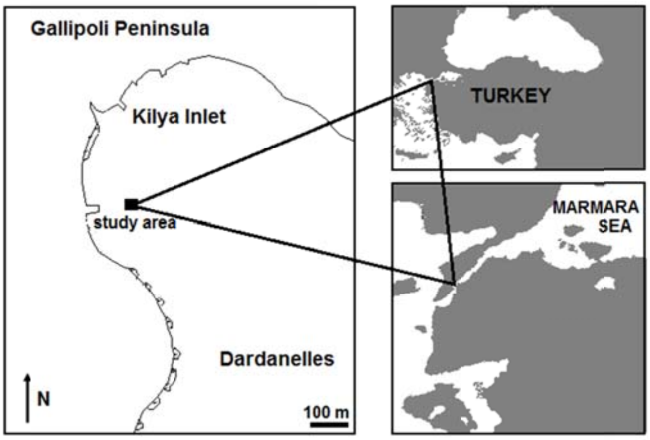

Figure 1. The map showing the study area.

Temperature, salinity, and chlorophyll-a levels were measured monthly in the study area. The temperature of seawater was measured by a mercury thermometer and salinity was measured by refractometer. The amount of chlorophyll-a was rated by using a method presented by Strickland and Parsons (1972). Four different collector models were arranged to determine the resistance of different collector models in the sea water and to measure their influences on mussel seeds' attachment rates. Among these models were natural fibers, one of which was the sisal ropes of 10 mm size and the other was jute ropes of 8 mm size, belonging to herbal fiber. Synthetic fiber ropes were polyamide net ropes of 40 mm size and 6 mm size ropes which were made from polypropylene.

During the first period of three months of the study, the collectors were monthly placed in the study area. Collector groups are consisted of 20 ropes having a length of 25 cm. To prevent falling of the mussel, plastic bags were attached under each collector. Collector groups were roughly hanged 1 m below the sea surface. The samplings were monthly made from these collectors along a period of three months. Using this system, sampling belongs to the collector groups placed in the water in February were taken out in March, April, and May. Likewise, sampling of the collector groups that were deployed in April was observed in May.

The particles of 4 cm were taken from the initial, middle and final parts of a collector of 25 cm length. Among these particles, all having 2.8 mm and more length were measured by 0.01 mm receptivity compass. All of the individuals counted by Dolphus's method under binocular microscope were smaller than 2.8 mm. A random sampling was made, and a total of 100 mussels was randomly measured under the microscope. The total length of all the individuals taken from the initial, middle and final parts were compared to the total length of the collector. As a result, the total mussel number of the whole collector, length groups were determined.

At the end of the period of first three months, the best attachment and resistant material were determined and used in the follow up of the research. In order to determine the monthly reproduction densities of the mussels in Dardanelles and ascertain the growth performances of the mussels that were attached to the collectors, determined collectors were continually set to the water in July 2002, October 2002, and January 2003. The samplings on the collectors were carried out until February 2004. To define the collector groups in a more practical way, determined collectors set to the water in February, March, April, May, June and January were named as rope 1, rope 2, rope 3, rope 4, rope 5, and rope 6, respectively.

Results

The study was performed for two years. The water temperature dropped in winter period and increased in the beginning of the spring. Later, it reached to high levels in summer times (Figure 2). In the study period, the salinity values of the seawater ranged between 19‰ and 26‰. It decreased gradually during the summer period and reached to minimum levels in winter months (Figure 2). The highest concentration of chlorophyll-a was measured in May 2002 as 8.757 μg/L and in June 2002 as 8.824 μg/L. A sudden decrease was recorded between June and July 2002. The lowest value of chlorophyll-a concentration was recorded in January 2004 with a value of 0.083 μg/L (Figure 3).

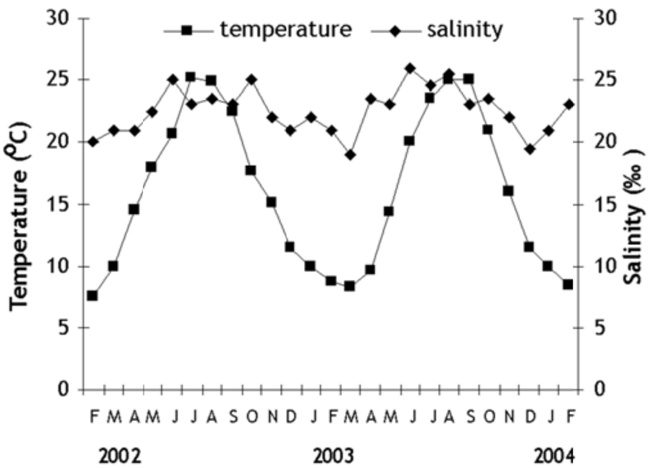

Figure 2. Variations in temperature and salinity values of sea water

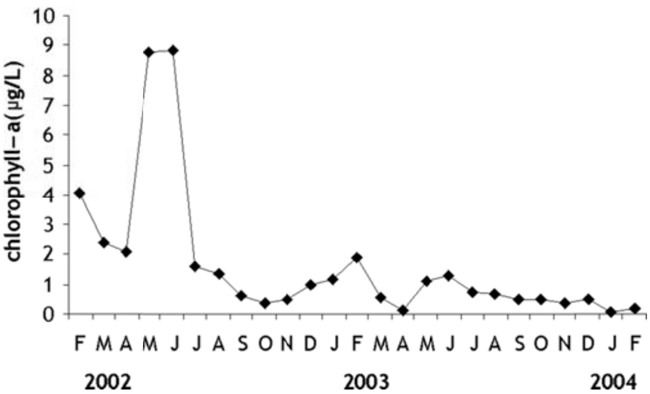

Figure 3. Chlorophyll-a changes observed in Dardanelles

Different collector materials (net rope, polypropylene rope, sisal rope, jute rope) were delivered to the sea in February 2002, March 2002 and April 2002. When the attachment rates of the mussels in collector groups delivered to water in February 2002 and first sampling was made in March 2002, a total of 44187 individuals on sisal rope 1, 48762 individuals on jute rope 1, 56595 individuals on polypropylene rope 1 and 53641 individuals on net rope 1 was counted (Table 1). Spat recruitment was not varied

Table 1. Mussel attachment amounts (100 cm²) in different collector models (net rope, polypropylene rope, sisal rope, jute rope)

Date	Sisal rope1	Sisal rope2	Sisal rope3	Jute rope1	Jute rope2	Jute rope3	P.propylene rope1	P.propylene rope2	P.propylene rope3	Net rope1	Net rope2	Net rope3
March	44187			48762			56595			53641		
April	37967	26227		31528	22303		59425	28087		48733	25491	
May	19112	15665	6957	12200	15781	10662	31387	21420	12375	32279	30258	7791

between collector types (p>0.05). When resistance of ropes was compared against the water effects, it was observed that jute ropes which are made of herbal material were broken into pieces and became unusable (Figure 4). The sisal ropes were worn off. Net and polypropylene ropes which are made of synthetic fiber did not show any deterioration. However, it was observed that some mussel seeds attached to polypropylene ropes which had comparatively less rugged surfaces, detached and fell because of the strong waves and currents. This was more observable especially toward the end of the study.

Figure 4. Collectors types (respectively, net rope, polypropylene rope, sisal rope, and jute rope) appearance after 3 months.

According to the attachment rate and resistance of rope net, collectors were preferred for follow up experiments and were set to the sea in July 2002, October 2002 and January 2003. The attachment rates and accordingly reproduction performances in these periods were monitored with net rope 1 collector between February 2002 and March 2002, March 2002 and April 2002 with net rope 2 collector, April 2002 and May 2002 net rope 3 collector, July 2002-August 2002 net rope 4 collector, October 2002-November 2002 net rope 5 collector, January 2003-February 2003 net rope 6 collector. The number of mussels in these periods were 53641, 25491, 7791, 7002, 1502 and 1679 individuals.

Spat settlement of mussel for net collectors was significantly different between months (p<0.05). Generally these mussels had a length range of 0.20-2.79 mm. The most of the pediveligers (≤0.47 mm) still managed to attach to these collectors either by sticking themselves directly on the mussels or passing through them (Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, Figure 10). However, at the sampling in August 2002 for net rope 4 collector deployed in July 2002, maximum mussel length was measured as 4.5 mm. Similar result for net rope 6 was determined and maximum mussel length was measured as 8.6 mm (Table 2 and Table 3).

Growth rates of mussels showed a quick progress between May and July in parallel with the rise in chlorophyll-a (Figure 3) and water temperature levels (Figure 2). While the biggest individual in net rope 1 collector for May 2002 was 2.38 mm, it became 17.7 mm in July 2002. Still, the biggest mussel that could be seen in May 2003 was maximum 60.8 mm whereas in July 2003, mussel length was recorded usually as between 52 mm and 67.1 mm. After this period, it was observed that these mussels started to hang down from the collectors and fall communally because of the strong waves and currents emerged especially as from November 2003. In February 2004 the length of the longest mussel was recorded as 71.1 mm presented at net rope 1 collector (Figure 5). Although spawning was observed throughout the year, mussel survival rate of spats was found too low in summer months especially in July and August.

The data obtained from net rope 2 and net rope 3 are shown in Table 2, Figure 6 and Figure 7. August 2002 sampling of the net rope 4 collector deployed in July 2002. 7010 individuals were collected in this period. Since the sea water temperature was high for the mussel spats and the surface of the collectors were covered with photophilic algae which blocked filtration of water, the mussels could not find much chance of surviving during this period. September 2002 sampling of this collector group collected 13908 individual and the biggest mussel found had a length of 0.97 mm. However, the mussels did not have a chance to survive longer in this area because of the similar environmental conditions. The sampling of this collector group carried out in October 2002, and collected 19845 mussel seeds had a maximum length as 1.09 mm. Many of the mussels managed to attach starting from this period had a bigger chance to grow in the following months. The biggest individual measured was a 52.2 mm in size on the net rope 4 collector that deployed for 19 months (Table 3).

Table 2. Mussel attachment amounts in net rope 1, net rope 2 and net rope 3 collectors (100 cm²).

Date	Net rope 1			Net rope 2			Net rope 3		
	<2.8 mm	>2.8 mm	Max. length (mm)	<2.8 mm	>2.8 mm	Max. length (mm)	<2.8 mm	>2.8 mm	Max. length (mm)
March 2002	53641		1.54						
April 2002	48733		1.65	25491		1.29			
May 2002	32279		2.38	30258	505	2.04	7791		1.99
June 2002	21875	700	11.3	19404	1133	7.0	9683		2.22
July 2002	10733	2052	17.7	10729	933	9.9	9210	2575	15.2
August 2002	3816	1541	24.2	12836	1619	12.6	5209	993	24.7
September 2002	12011	825	27.9	10345	316	19.5	**	**	**
October 2002	9900	805	29.6	10013	363	20.0	**	**	**
November 2002	9309	350	30.9	11646	292	28.2	4326	503	28.3
December 2002	9436	459	35.8	10309	670	34.7	**	**	**
January 2003	6389	378	43.9	3941	567	38.7	**	**	**
February 2003	6564	363	46.4	4621	827	40.7	3903	382	36.5
March 2003	3689	419	50.7	3858	686	44.5			
April 2003	5077	450	52.4	3010	624	44.3	3428	342	41.7
May 2003	2255	607	60.8	3255	724	52.5	*	*	*
June 2003	2067	501	62.7	1524	366	55.8	*	*	*
July 2003	2724	610	67.1	2380		60.3	*	*	*
August 2003	3444	770	69.9	2631	354	64.7	*	*	*
November 2003	1951	332	70.4	**	**	**	*	*	*
February 2004	4342	176	71.1	2248	367	70.1	*	*	*

* sampling loss

** sampling error

Table 3. Mussel attachment amounts in net rope 4, net rope 5 and net rope 6 collectors (100 cm²).

Date	Net rope 4			Net rope 5			Net rope 6		
	<2.8 mm	>2.8 mm	Max. length (mm)	<2.8 mm	>2.8 mm	Max. length (mm)	<2.8 mm	>2.8 mm	Max. length (mm)
August 2002	7002	8	4.5						
September 2002	13908		0.97						
October 2002	19845		1.09						
November 2002	17217	7	12.6	1520		0.93			
December 2002	19850	50	5.4	4500		1.47			
January 2003	10720	100	4.0	3346	11	5.4			
February 2003	12712	466	8.2	5650	62	3.9	1679		1.18
March 2003	16433	1237	7.0	10783	625	7.3	7170	358	8.6
April 2003	6587	1216	11.0	5779	295	8.8	6829	191	10.0
May 2003	9750	2379	19.3	8364	1517	21.5	11291	533	11.2
June 2003	4170	1247	28	3979	1304	34.7	7212	741	18.6
July 2003	2914	1357	38.3	1651	555	38.6	**	**	**
August 2003	1548	594	46.0	2222	394	39.8	3085	1079	33.8
November 2003	2770	316	46.4	3629	435	41.5	3005	439	37.5
January 2003	**	**	**	2356	117	31.1	2356	117	31.1
February 2004	4325	251	52.2	3882	207	45.8	4363	21	30.8

* sampling loss

** sampling error

It was observed that most of the mussels attached to net rope 6 collector drew apart and fell after November 2003. While 439 individuals bigger than 2.8 mm were determined on this collector in November 2003, in January 2004 a total of 117 individuals and in February 2004 a total of 21 individuals, were found (Table 3).

Photophilic algae such as *Cladophara* sp., *Gracilaria* sp., *Codium* sp., *Ulva* sp., meadow such as *Zostera* sp. and bryozoa such as *Bugula plumosa* Palas 1766 were observed at the lowest level in April and they showed an increase with the temperature. In both years, it was determined that macroalge amounts decreased starting from November, got infrequent during December and not observed in January. *B. plumose.* could be seen in low numbers during the winter period. In both years of the study, *Balanus* sp. and polychaete species on collectors were observed mostly in the summer and in the winter months, respectively.

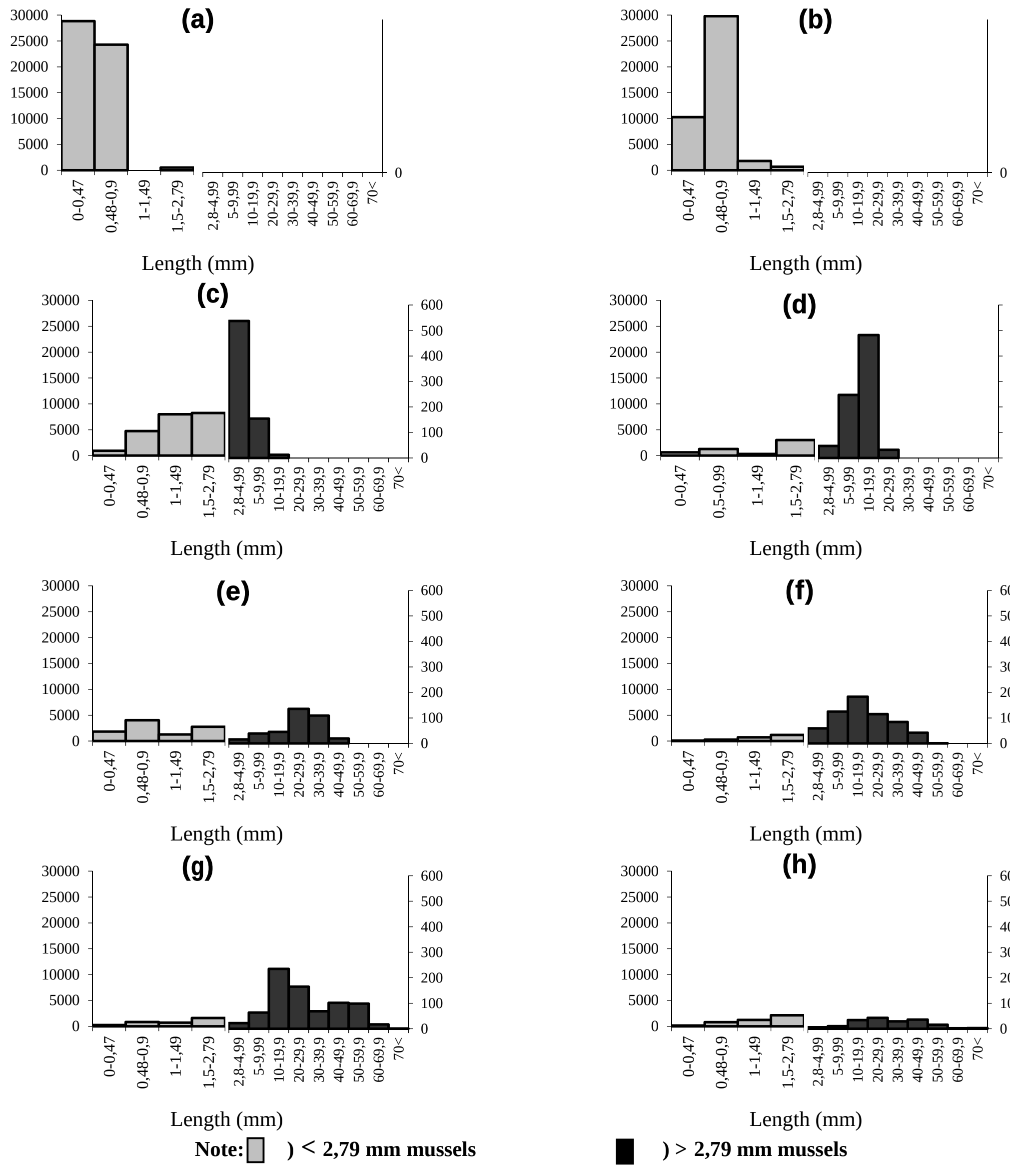

Figure 5. Mussel attachment and growing performances in net rope 1 collector (number/100 cm^2); a) March 2002, b) April 2002, c) June 2002, d) October 2002, e) February 2003, f) May 2003, g) August 2003, h) February 2004.

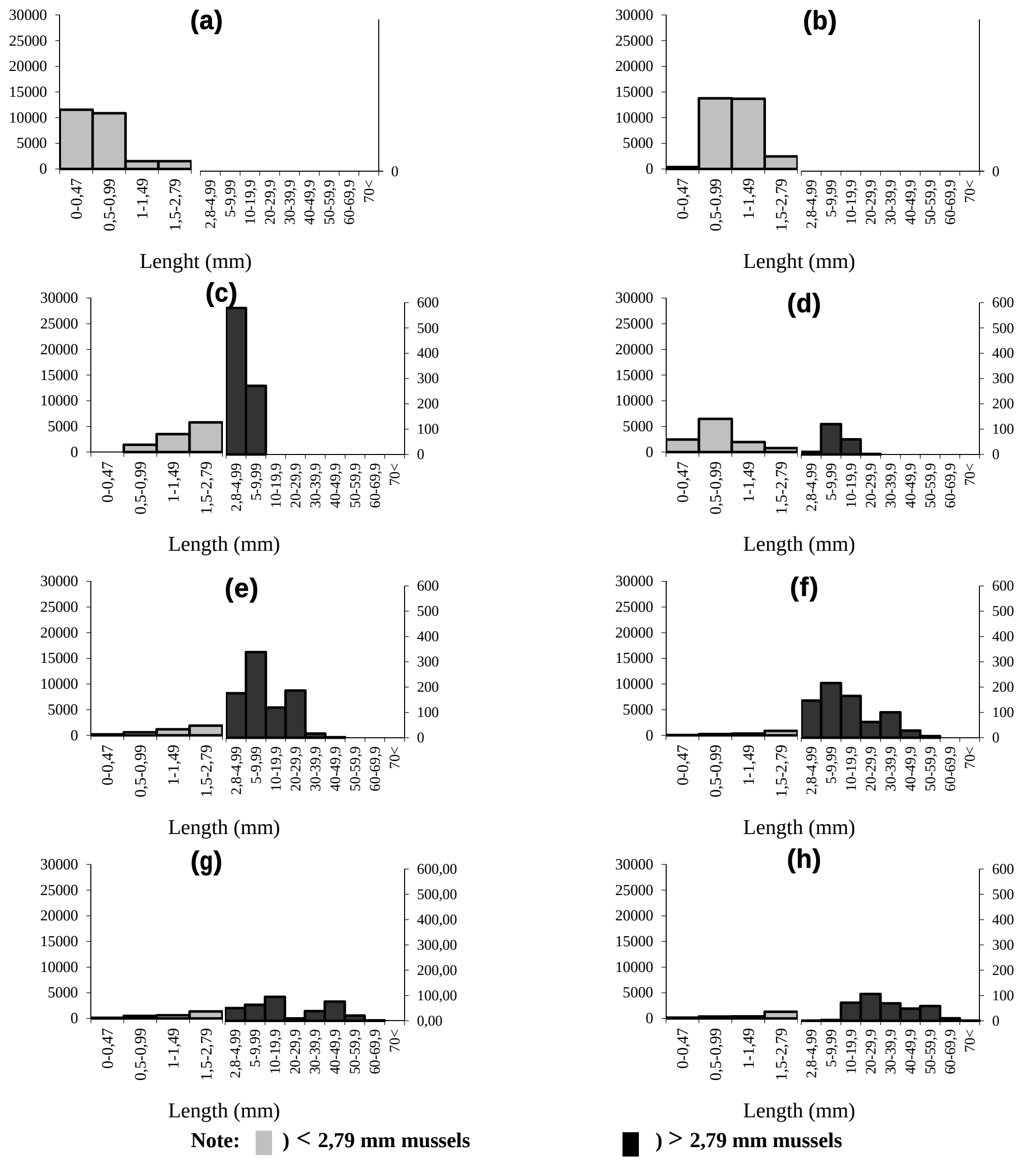

Figure 6. Mussel attachment and growing performances in net rope 2 collector (number/100 cm^2); a) April 2002, b) May 2002, c) July 2002, d) November 2002, e) March 2003, f) June 2003, g) August 2003, h) February 2004.

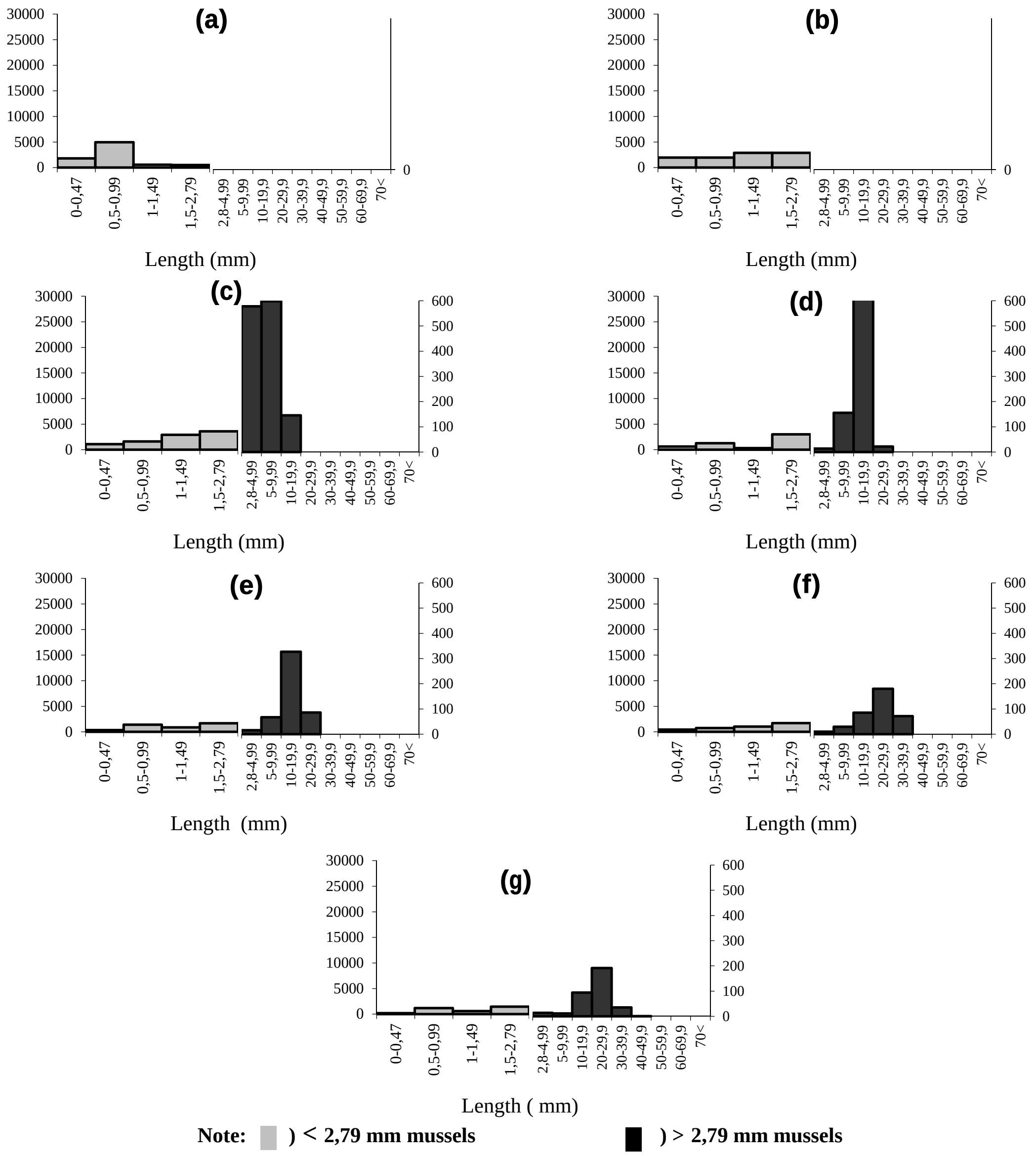

Figure 7. Mussel attachment and growing performances in net rope 3 collector (number/100 cm^2); a) May 2002, b) June 2002, c) July 2002, d) August 2002, e) October 2002, f) January 2003, g) April 2003

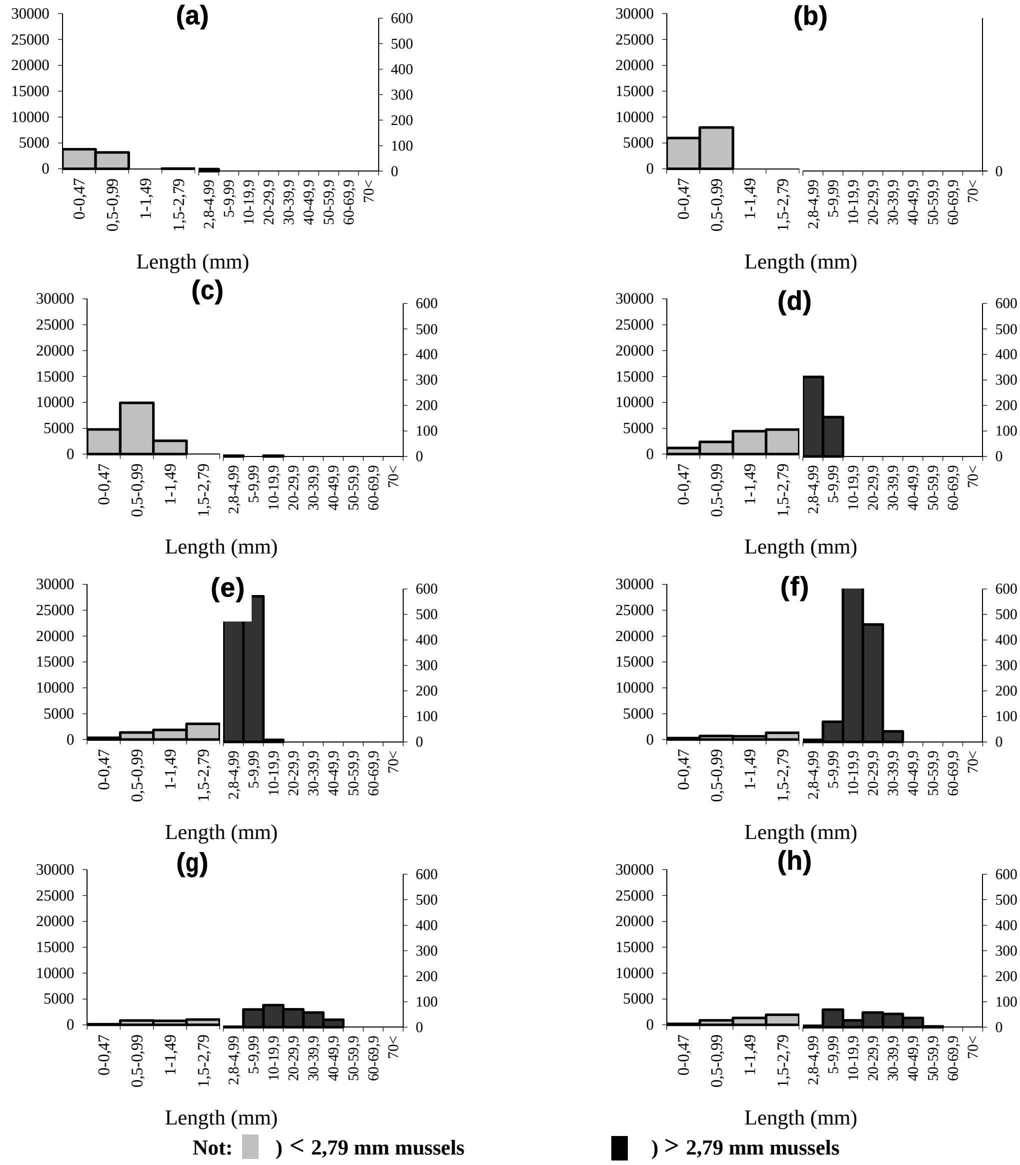

Figure 8. Mussel attachment and growing performances in net rope 4 collector (number/100 cm^2); a) August 2002, b) September 2002, c) November 2002, d) February 2003, e) April 2003, f). July 2003, g) November 2003, h) February 2004.

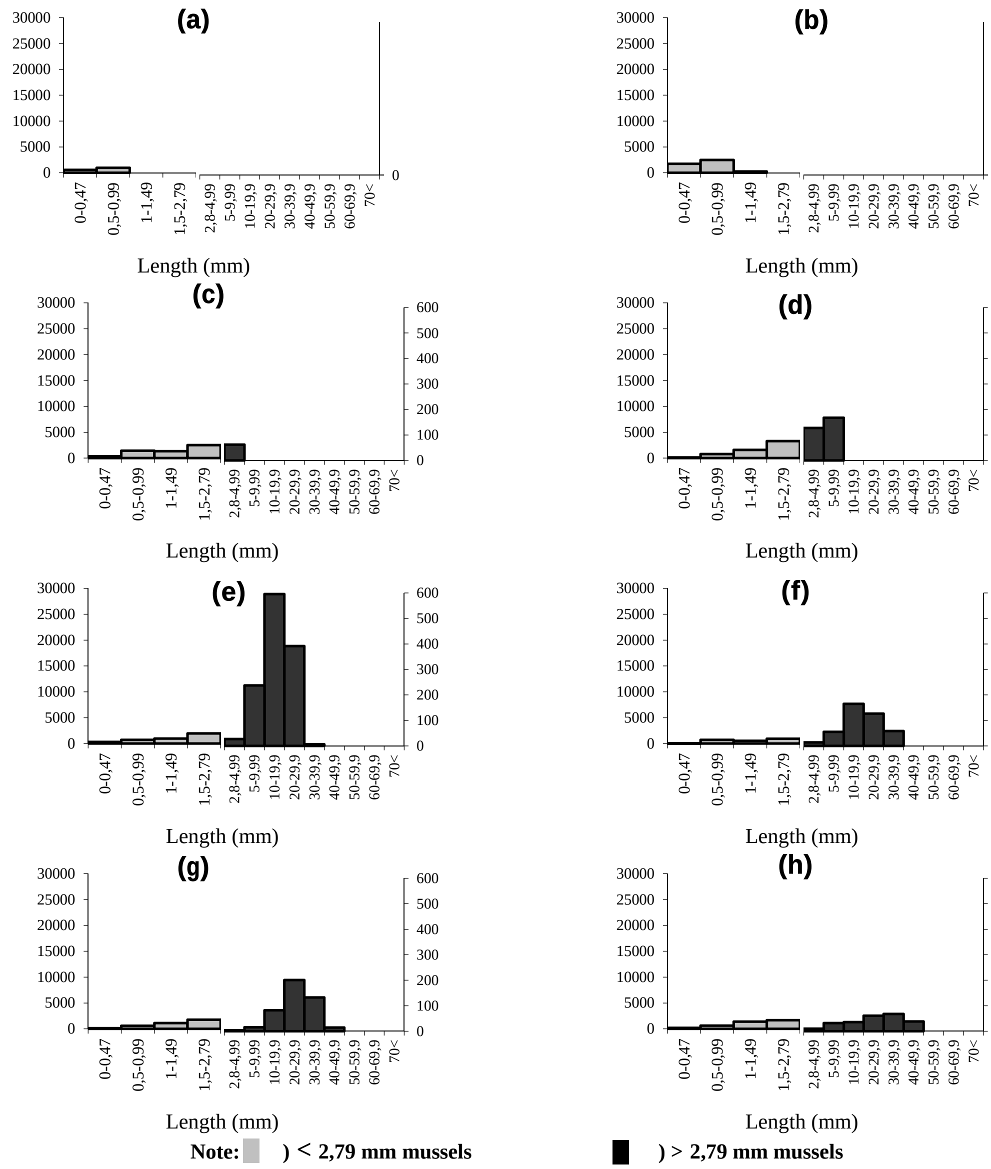

Figure 9. Mussel attachment and growing performances in net rope 5 collector (number/100 cm^2); a) November 2002, b) December 2002, c) February 2003, d) April 2003, e) June 2003, f) August 2003, g) November 2003, h) February 2004.

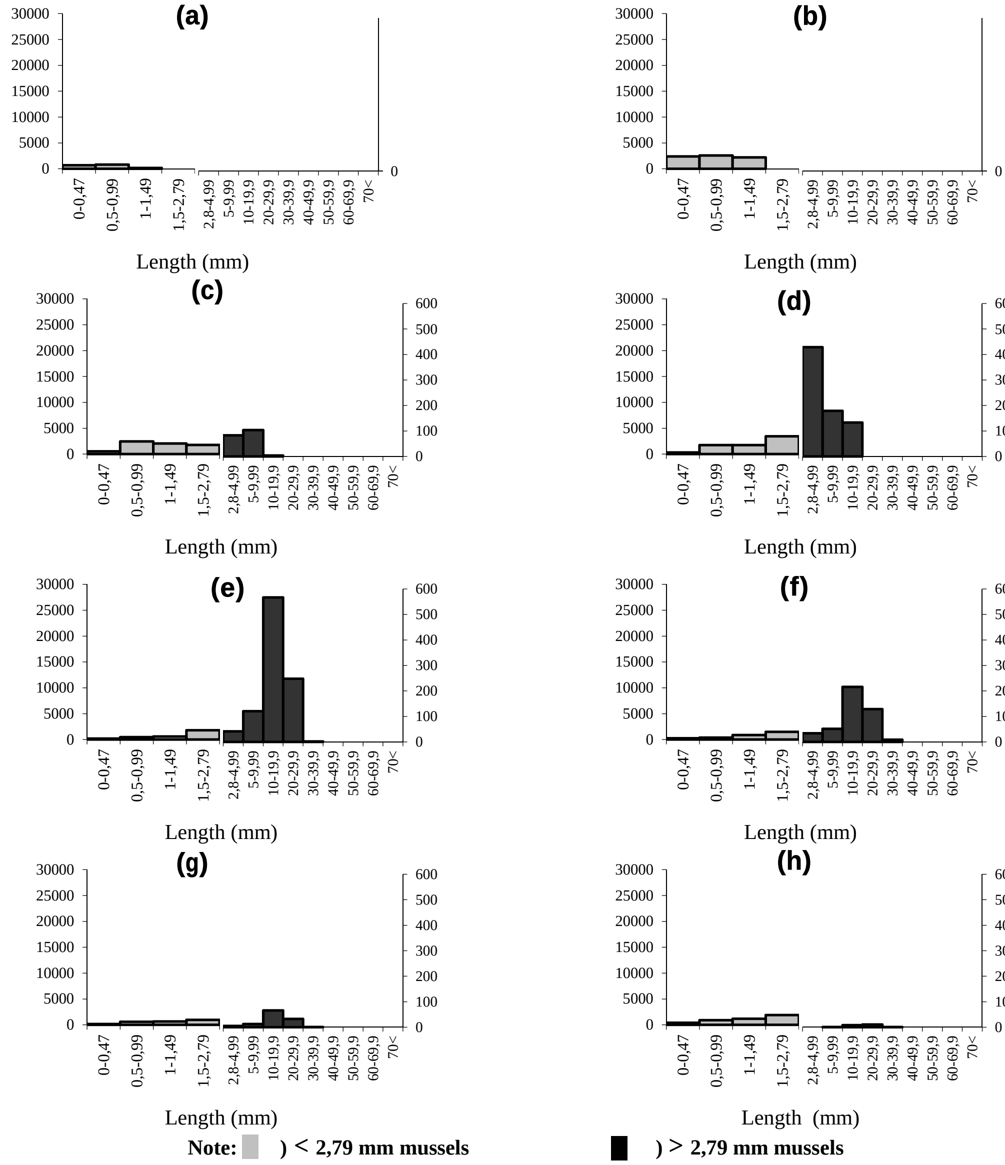

Figure 10. Mussel attachment and growing performances in net rope 6 collector (number/100 cm^2); a) February 2003, b) March 2003, c) April 2003, d) June 2003, e) August 2003, f) November 2003, g) January 2004, h) February 2004.

Discussion

Spat settlement in bivalves are influenced by many factors like collector design (Lekang et al., 2003), location (Garcia Alcázar et al., 1989), predation (Filgueira et al., 2007) and immersion time (Yıldız et al., 2010; Yıldız and Berber, 2010). Especially, composition and structure substrate are significantly effective on attachment and growth rates of the mussel spats (Davies, 1974; Dare et al., 1983; Filgueira et al., 2007). Different natural and artificial substrates are used to collect the mussel spats. In this study, similar results about performance of mussel attachment among collector types were obtained (Table 1). Sisal rope and jute rope collectors had low resistance in sea water. These collectors are made of dead herbal essences and they consist of cellulose. As known, microorganisms in sea water destroy cellulose (Çelikkale et al., 1993). According to our results, net rope and polypropylene ropes were the most durable materials against sea water corrosion. Polypropylene ropes that have the material of synthetic fibre are more resistant to sea water, but some of the mussels on these collectors gradually drew apart and fell. This situation can be explained with the less rugged surfaces of polypropylene ropes compared to other collector materials. In the period of first three months, wear and tear was observed on net ropes consisted of synthetic fibre. We prefer this material became it is more durable, and it is made of unusable fish nets. Therefore, because of their low cost, net collectors could be extensively preferred than the others for both commercial and scientific purposes

In this study, reproduction was observed all around the year. These results are similar with the studies carried out in Yugoslavia (Margus and Teskeredzic, 1986), Canada (Mallet and Carver, 1991) and Galicia Gulf in Spain (Camacho et al., 1991). The density of mussel recruitment in Dardanelles increased between February and April and reached its peak level specifically between February and March. Mussel collectors should be set to the water a few months earlier than the estimated reproduction period in the region (Okumuş 1993; Karayücel et al., 2002). If the collectors are set to the water earlier, their surfaces might be covered with fouling organisms. Yet, there may be no free seat to be attached the mussel larvae during reproduction period. However, if they are set to water later, the amount of spat settlement can be too low (Mason, 1971). We can suggest that mussel collectors used in the study area can be set to sea at the end of December or at the beginning of January.

Growth rate of mussels is dependent on trophic conditions and temperature (Gosling, 2003). During the study, maximum growth rates was observed between May and July. Widdows et al. (1979), Page and Hubbard (1987), Beiras et al. (1993), Karayücel and Karayücel (1997) stated the significance of the amount of chlorophyll-a as a vital element in determining the growth of mussels. In this study, especially between May 2002 and July 2002 the chlorophyll-a value was the highest, mussel length reached to 17.7 mm for net rope 1. Similar results were obtained from other collector groups during this period. Growth rate started to decline from August to November, and reached the lowest value from December to February. Similar data were recorded by Seed (1969), Fuentes et al. (1998), and Yıldız and Lök (2005).

After the net rope 4 was deployed in July 2002, it was collected in next month. A total of 7010 mussel seeds were attached and 99% of these were smaller than 1 mm. Similar behavior was observed in September and October 2002 (Figure 10). Therefore, we indicate that mussels in the stages of pediveliger and post larvae are sensitive to water temperature, consequently, they have no survival chance (Tsuchiya, 1983). Suchanek (1985) pointed out that mortality rates may be higher in summer months when the mussel seeds are very sensitive to water temperature. Photophilic algae such as *Cladophara* sp., *Gracilaria* sp., *Codium* sp., *Ulva* sp., meadow such as *Zostera* sp. and bryozoa such as *B. plumosa* were observed on the collectors during the summer. Accordingly, since the filtration rate of mussels drop, a significant increase in their mortality rates was recorded. Net rope 1, net rope 2 and net rope 3 collectors were less affected by environmental conditions comparing to net rope 4 during the summer. The main reason for this can be explained with the mussel specimens on the collectors having a certain size.

Ramirez and Martinez (1999) estimated that 92% of the mussel seeds attached to different collector materials were in pediveliger phase and continued to grow. Beukema and Vlas (1989) and Martel and Chia (1991) noted that the rare appearance of big post larvae (10.49 mm) observed in their collectors. According to our results, the length of the biggest mussel was measured as 4.5 mm for net rope 4 collector in August 2002. Similarly, for the sampling performed in March 2003 in the net rope 6 collector the maximum length measured was 8.6 mm. Evidently, this might be regarded as a proof that mussel seeds find new substrate types to attach when they cannot find a suitable substrate. These results were in accordance with the studies of Ferran et al. (1990) and Villalba (1995).

After 18-24 months, the highest length values belong to individuals for net rope 1 was measured as 69.9 mm and 71.1 mm, respectively. Besides, different length classes were noted during the study. This showed that attachment continued throughout the year and first attachmed individuals reached to marketable size (<50 mm) in 18 months. Mussel specimens that are bigger than 50 mm are accepted as marketable (Karayücel and Karayücel, 1997; Lök et al., 2007). However in commercial companies the mussels are removed from each rope, cleaned, and distributed onto three new ropes within 5 or 6 months after attachment. Holiday et al. (1993) noted that growth, survival, and retention of spat in the nursery are affected by spat density on collectors. Thinning accomplishes two things: it decreases the risk of clumps of mussels falling off the ropes and it increases growth rate (Perez and Roman, 1979; Camacho et al., 1991; Gosling, 2003). If thinning is used at net rope 1 and net rope 2 mussels can reach marketable size less than 18 months so that the harvest time can be reduced.

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