The impact assessment of cage aquaculture on benthic communities along the south eastern Black Sea

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Abstract

The present study was conducted to examine the impact of cage aquaculture on benthic communities in coastal areas (depth 25 to 50 m) from fish farming operations located along the southeastern Black Sea (Ordu-Perşembe, Trabzon-Yomra and Rize central). Sampling was conducted seasonally from April 2007 to 2009. Sediment samples were taken using Ekman Grab (box core- 0.04 m^2). Temperature, salinity, and water velocity were periodically measured to determine influencing sedimentary organic matter in the sediment, oxygenation, and anoxic conditions. In addition, grain size of sediment, organic carbon content, and distribution of benthic communities were investigated. In order to determine benthic impact of fish farms on the region, Shannon – Wiener diversity index (H'), AMBI (AZTI Marine Biotic Index) and M-AMBI (Multivariate- Marine Biotic Index) indices were used. Results of current study showed that benthic zone ecological quality of stations with number 01, 02, 03, and 04 at Ordu-Perşembefish-farming habitat was found to be very low. In autumn 2008, there were 3 species which belonged to *Capitella capitata* (844 individuals/m^2), *Capitella* sp. (133 individuals/m^2), and *Heteromastus filliformis* (311 individuals/m^2) at OP-01 station. In addition, the impact of Trabzon-Yomra fish-farming activity on benthic communities was low. The degree of exposure for Rize fish-farming area in all seasons was quite low, which was not a significant negative impact.

Keywords: Cage culture, Benthic organisms, Ecological quality, Marine biotis indices, Black Sea, Turkey

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Introduction

Aquaculture has developed into a major industry in coastal areas around the world. Augmented by the growing demand for aquatic products intensive; cage farming increased rapidly following the early salmon farming operations initiated in Norway in the 1970s. In Turkey, thefirst net cage, fish farming operations in inland waters (Lake Beşgöz) began in 1980 consisting of trout farms,(Çelikkale *et al.*, 1981), followed by commercial sea bream and sea bass farming in coastal seas in 1985 (Topçuand Gönül 1997; Savaş *et al.*, 2006; Emre *et al.*, 2008). Studies by the Central Fisheries Research Institute inTurkey were initated in 1990 to investigate whether the Black Sea, which has low salinity and brackish water, could support cage farming of freshwater rainbow trout. The first commercial sea cage system in the region began to operate with rainbow trout, and seabass farming facilities in the 1990s. Since these earlier times the capacity of the enterprises engaged in cage fish farming have increased significantly (Tellikarakoç *et al.*, 2007). Cage systems in the Black Sea are heavily located in Ordu-Perşembe, Trabzon-Yomra, and Rize-Central since these areas are sheltered, and are therefore less affected by the prevailing wind and high waves.

Net cage aquaculture can potentially have varying degrees of negative impact on the surrounding environment depending on fish species, farming methods, stock density, food typed, hydrography of the area, and fish farm management. Nutrients such as phosphorus, and nitrogen, as well as other chemical residues are released into the water column from the breakdown of excess feed, as well as through fish excretion and fecal waste often leading to nutrient loading, and eutrophication. Moreover, unconsumed feed and fecal material accumulating on the bottom can stimulate microbial production causing hypoxic or anoxic conditions, negatively impacting benthic communities. Environmental impacts are not restricted to areas within cages, as wind, waves and bottom currents can also allow nearby areas to be affected by farming activities. Farming practices such as maintaining high densities of fish and placing cages in areas and at depths unsuitable for farming can be particularily detrimental. Fish farms located in closed or semi-closed bays may result in high turbidity, soil degradation, and the deterioration of water quality and overall ecosystem health. Many studies have showed that fish farms, especially, in places where the water circulation is low and water depth is inadequate cause negative impacts on the marine ecosystem and pollution in water column and sediment (Karakassis and Hatziyanni, 2000; Kalantzi and Karakassis, 2006).The most common impact is on benthic communities resulting from organic enrichment of bottom sediments which often lead to significant changes in the composition and community structure (e.g. abundance, dominance, species richnes) of resident macrofaunal organisms (Pearson and Rosenberg, 1978; Drake and Arias, 1997). Thus, organic carbon content of sediment is one of the most important criteria used to determine ecological environment quality (Kalantziand Karakassis, 2006; Borja *et al*., 2009), and it is also used to determine the degree of the effect on benthic ecosystem by relating the total organic carbon accumulated to benthic fauna diversity (Pearson and Rosenberg 1978; Hyland *et al*., 2005; Kalantziand Karakassis, 2006). Changes caused by the accumulation of organic matter in benthic fauna make a group of organisms with high tolerance (some Polychaeta) dominant, while many some other polychaetes are sensitive to organic enrichment (Pearson and Rosenberg, 1978; Yücel-Gier *et al*., 2007).

The effects of cage aquaculture on the environment have been studied in many parts of the world (Drake and Arıas, 1997; Borja *et al*., 2000; Karakassıs *et al*., 2000, Kalantzı and Karakassıs, 2006).

These studies determine dorganic carbon content of the sediment as one of the most important criteria used to determine ecological environment quality. They also determined the degree of effect on benthic ecosystem by relating the total organic carbon accumulated to benthic fauna diversity.

However, the number of similar studies are limited in Turkey (Ergen *et al.*, 2004; Koçak *et al.*, 2004; Doğan *et al*., 2007;Yücel-Gier *et al.*, 2007; Dağlı *et al*., 2008), especially in the Black Sea.To our knowledge no published literature related to the environmental effects of cage aquaculture in the Black Sea region currently exists. The main purpose of this study is to determine the degree of impact of present enterprises in three regions of cage farming in the Black Sea in order to supplement the lack of studiesin this area.

Materials and method

Study area and sampling

The present study was carried out seasonally during two years (between April 2007 and April 2009) to determine effects of fish farmson the benthic region of Black Sea-Turkish coasts at Ordu-Perşembe (OP), Trabzon-Yomra (TY), and Rize Central (RM) (Fig. 1).

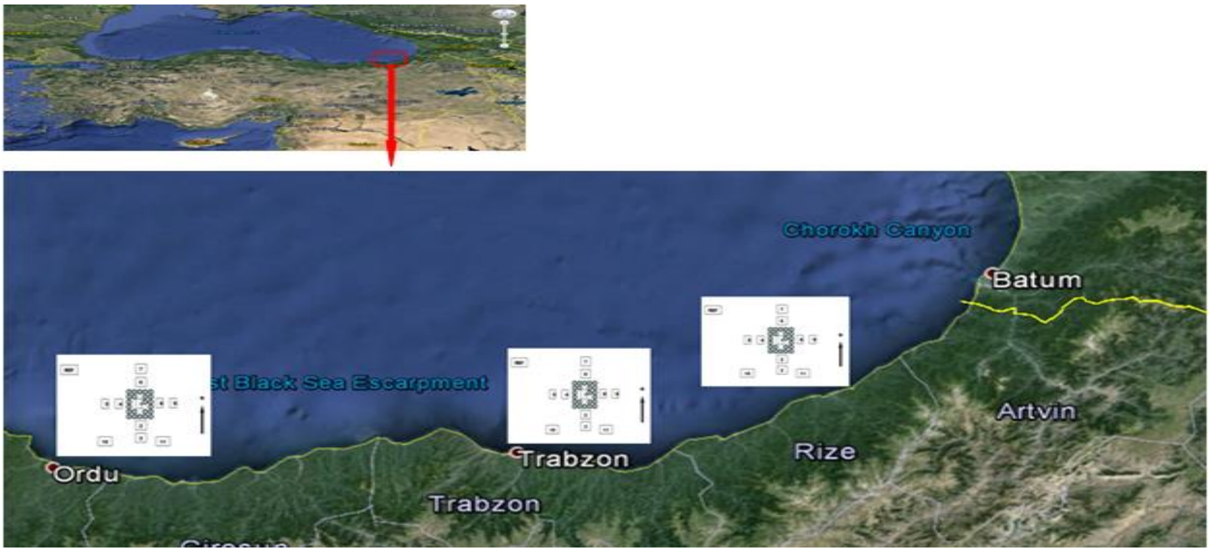


Figure 1: Study area, Ordu, Trabzon, Rize.

The position of the sampling sites in the center and around the cage culture in all three regions was determined in the form of a plus (+) plan. The first sampling point for each station was selected atthe center of the cage system. Other sampling points were chosenwith 50 m intervals away from the outer edge of each cage system. Also two more sampling points were set at to sides of the base of the plus (+) at each cage system. In order to determine the impact of coastal regions, a reference sampling site was chosen some 1 km off the two stations and the cage system in the reverse direction of water currents, and unaffected by farming units (Fig. 2). Regional depths, coordinates, and sediment types for the stations are presented in Table 1.

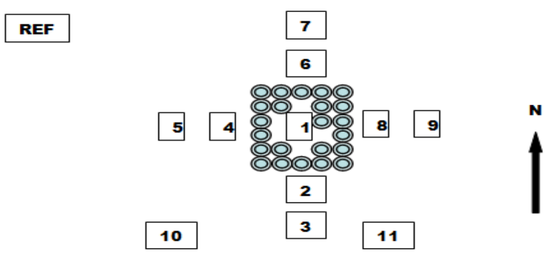


Figure 2: Cages layout and sampling points .

Table 1: Regional depths (m), coordinates, and sediment types of the sampling stations.

	ORDU			TRABZON			RIZE		
Sampling points	**Depth (m)**	**Coordinates**	**Sediment type**	**Depth (m)**	**Coordinates**	**Sediment type**	**Depth (m)**	**Coordinates**	**Sediment type**
Ref	40	N 41°04'599" E 37°47'089"	clayey	55	N 40°58'433" E 39°50'894"	Mudy+ sandy	38	N 41° 2'50.95" E 40°31'19.89"	sandy
1	39	N 41°05'012" E 37°46'986"	mudy	54	N 40°58'119" E 39°51'748"	sandy	28	N 41° 2'11.28" E 40°32'16.44"	clayey
2	30	N 41°05'018" E 37°46'872"	Sandy+ clayey	45	N 40°58'005" E 39°51'714"	sandy	16	N 41° 02'04.39" E 40°32'10.99"	sandy
3	10	N 41°05'031" E 37°46'805"	sandy	39	N 40°57'962" E 39°5' '681"	sandy	14	N 41° 02'03.02" E 40°32'09.85"	sandy
4	40	N 41°05'074" E 37°47'009"	mudy	55	N 40°58'140" E 39°51'670"	sandy	32	N 41° 2'12.57" E 40°32'13.61"	sandy
5	41	N 41°05'100" E 37°47'042"	sandy	55	N 40°58'150" E 39°51'604"	sandy	30	N 41° 2'13.38" E 40°32'11.83"	sandy
6	45	N 41°04'987" E 37°47'115"	Gravelly+ sandy	65	N 40°58'267" E 39°51'811"	Sandy+ mudy	33	N 41° 2'18.24" E 40°32'22.04"	Sandy+ clayey
7	50	N 41°04'966" E 37°47'172"	sandy	70	N 40°58'314" E 39°51'831"	Mudy+ sandy	36	N 41° 2'19.61" E 40°32'23.13"	Sandy+ mudy
8	37	N 41°04'919" E 37°46'972"	mudy	56	N 40°58'140" E 39°51'857"	sandy	27	N 41° 2'09.86" E 40°32'19.49"	sandy
9	37	N 41°04'888" E 37°46'968"	mudy	56	N 40°58'137" E 39°51'910"	Mudy+ sandy	25	N 41° 2'09.19" E 40°32'21.05"	clayey
10	20	N 41°04'482" E 37°46'639"	mudy	35	N 40°58'088" E 39°51'28"	sandy	10	N 41° 1'47.65" E 40°32'41.34"	sandy
11				32	N 40°57'833" E 39°51'936"	sandy	10	N 41° 1'43.57" E 40°31'27.05"	sandy

Sediment samples were collected using an Ekman Grab (Box Core) sampler with a 0.04 m^2 area. The obtained benthic samples were diluted in sea water and fixed in 4% formaldehyde for later identification. In the laboratory, sediment samples were sieved throught 1 mm and 0.5 mm mesh and washed with freshwater in order to remove the sludge and formaldehyde.

Macrozoobenthic organisms in benthic samples were firstly separated according to systematic groups and species were identified using stereo-microscope and light microscope. The identified species were counted for future data processing (e.g. statistical analysis). All the organisms sampled in the study were kept in 70% ethyl alcohol (Ağırbaş 2006; Başçınar and Gözler, 2010).

In grain size analysis of sediment samples, a homogenization was applied and grain size distribution was determined via grain size curve and wet and dry sieve analysis technique with ASTM (1990) standard methods (Friedman *et al*., 1978; Larsont *et al*., 1987). Sediment type was identified according to Friedman and Sanders (1978) method of sediment classification. Preliminary preparations for organic carbon analysis in the sediment were done according to Loring and Rantala (1992) and the method was applied according to Verardo *et al*., (1990).

During the study period, temperature and salinity measurements of water column of the fish farming facilities were done with AANDERA-RCM9 CD probe and YSI6800 CTD. In order to determine the direction and speed of water currents, from the surface to the bottom, RD-DOPLER Work horse current meter was deployed. The current value was measured on a monthly basis on the coasts ofPerşembe, Trabzon and Rize (Alkan *et al*., 2003).

The degree of benthic impact of fish farms on their adjacent regions was determined using Shannon – Wiener diversity index (H'), AMBI(AZTI Marine Biotic Index) and M-AMBI (Multivariate-Marine Biotic Index) (Tables 2, 3, and 4). Shannon – Wiener diversity index, AMBI and M-AMBI indices are widely used by numerous researchers in the Mediterranean and Black Sea to determine the effects of coastal culture production on marine ecosystems (Pearson and Rosenberg, 1978; Drake and Arias, 1997; Borja and Muxıka, 2005; Kalantzi and Karakassis, 2006; Borja *et al*., 2009; Dehghan, *et al*., 2012). Shannon – Wiener diversity index and the classification scheme (Todorova *et al*., 2008) were used to determine the ecological quality of the area (Table2). Kolmogorov-Smirnov test was used for water quality parameters, Spearman correlation was used to find out the relationships between variables, and Kruskal Wallis H test was used to detect the differences between data groups.

Table2: Diversity index (H') classification values (Todorova *et al.*, 2008).

Water bodies with muddy sediments					
Ecological status	**High**	**Good**	**Moderate**	**Poor**	**Bad**
H' average	3.6	2.9	2.2	1.5	0.7
Range	H' ≥ 3.3	3.3 > H' ≥ 2.5	2.5 > H' ≥ 1.8	1.8 > H' ≥ 1.1	1.1 > H' ≥ 0

Table 3: AMBI classification values (Todorova *et al.*, 2008).

AMBI					
Ecological status	**High**	**Good**	**Moderate**	**Poor**	**Bad**
Range	0.0<AMBI ≤1.2	1.2<AMBI≤3.3	3.3<AMBI≤4.3	4.3<AMBI≤5.5	5.5<AMBI≤6.0 Azoik sediment(7.0)

Table 4 : M-AMBI classification values (Todorova *et al.*, 2008).

	M-AMBI				
Ecological status	**High**	**Good**	**Moderate**	**Poor**	**Bad**
Range	M-AMBI≥0.85	0.85>M-AMBI≥0.55	0.55>M-AMBI≥0.39	0.39>M-AMBI≥0.20	0.20>M-AMBI

Results

Ocenographic Data

Hydrographyc data showed a great variability in temperature values over months. The average temperature at the surface layer (0.5 m) ranged from 7.37 (January) to 27.29 ºC (August); 7.93 (January) to 28.16 ºC (August) and 7.98 to 28.90 ºC at the Persembe, Yomra and Rize coasts, respectively. At the bottom layer (Ordu: 10-50m; Trabzon: 35-70m: Rize: 10-38m), the values were as follows:7.45 (February)-26.40 ºC (September), 7.53 (February)-24.10 ºC (September) and 7.72-28.45ºC, respectively. Seasonal changes in temperature were statistically significant at surface (p<0.05), and bottom layers (p<0.01) for each station. Surface salinity ranged from 16.71 to 18.93ppt; 16.97 to 18.72 ppt and 16.61–19.59ppt, in Persembe, Yomra and Rize, respectively. Bottom salinity ranged from 17.36 to 19.16ppt; 17.69 to 19.52ppt and 16.97–20.01ppt in Persembe, Yomra and Rize, respectively. While the surface salinity changed among the stations, it was not significant, the difference among stations at bottom layer in Trabzon (100m) was statistically significant (p<0.05). Seasonal salinity changes at the bottom and surface stations in the three regions were statistically significant (p<0.05).

When the seasonal variation of the current in the cage systems in Perşembe, Yomra and Rize in the Black Sea was examined, it was observed that average current rate was 38 mms^{-1} (25–58 mms^{-1}) and dominant flow direction was to the southeast and southwest on Perşembe coast which is close to the wind and flow of west and northwest direction as a result of geographical structure. In the region, water body and suspended solid transport was parallel to the stream. The gulf of Yomra with a cape on the west is close to western and, in part, northwestern winds. Dominant flow direction in cage area was observed as to the southwest in spring and autumn, to the south in summer, and to the northwest in winter. Average flow velocity around the cage system was determined as 53 mms^{-1} (ranging from 33 to 117 mms^{-1}).

In the form of an open gulf, the coasts of the central district of Rize, in part, prevent the currents from the west with the help of Rize port in the west. The region is under the influence of east-flowing currents, which is the effective current direction of the Black Sea coast. Besides, west-flowing coastal currents of Batumi gyre, an anticyclonic vortex also affect the area. Depending on these factors, the current flowing to the east in spring flows in the southwest direction in autumn and winter.The rate of the flow around the cage systems in the east of Rize port was measured as an average of 48 mms^{-1} (ranging from 30 to 91 mms^{-1}).

Sediment quality

On examining the sediment grain size analysis, it was observed that present bottom sediment was mainly in clay-size with a uniform structure at Perşembe station. The sediment on the coasts of Yomra was in the range of fine sand and clay. While in the central and offshore parts of the cage systems it was mainly made of clay, a uniform distribution of mostly sand was detected at stations close to the coast and at reference stations. Deep sediment in and around Rize cage systems, was in a uniform structure and distributed mainly in the range of fine sand and clay. When the differences between the stations were analyzed, it was observed that there was mainly clay distribution in the central and offshore parts of the cage systems, and sand dominated structures close to the shore and reference stations.

On evaluating the organic carbon content of the sediment in fish farming area and at reference stations, the lowest average values (sometimes below the limit of C< 0.20%) were observed at the stations in Rize and the fish farming areas contained organic carbon close to the regional reference level. In samples taken from Perşembe the average organic carbon content was relatively higher, and the maximum values reached up to 4.5 %. Organic carbon values were observed to be high (>3%) at timesor throughout the timeof sampling in Yomrafish farming area. In addition, unlike Ordu, organic carbon content of the samples taken from Yomra stations had a time-dependent increase.

Biological parameters

In determining the degree of pollution effect from the plants in Ordu-Perşembe farming area, diversity (H'), AMBI and M-AMBI indices were used and the results are shown in Table 5. It was observed that the diversity and number of the species was lower at stations number OP-01, OP-02, OP-03, and OP-04; whereas, the diversity and number of species increased away from the cage system. Index values were observed to be high under the cage system, increasing away from the cage system and its effect. At stations number OP-01, OP-02, OP-03, OP-04 in the field of aquaculture in the region, ecological quality was found to be at a very low level (Table 5). It was observed that the degree of quality increased and ecological quality improved away from the cages.

In autumn 2007, there were a total of 533 individuals/m^2, three species, and 267 individidiuals/m^2 of *C. capitata* as indicator species in benthic macrofauna at OP-01 station. There were 311 individiuals/m^2 and 2 species at OP-02 station. There were 444 individuals/m^2, and 5 species, and 178 individuals/m^2 of *H. filliformis* as indicator species at OP-03 station. There were a total of 1022 individuals/m^2 with 7 species, 89 individuals/m^2 of *Capitallides*, 553 individuals/m^2 of *H. filliformis*, and 44.4 individuals/m^2 of *Mytilus galloprovincialis* as indicator species at OP-04 station. According to Bray-Curtis similarity analysis of species diversity between stations in autumn, maximum similarity was found at 60% between reference station and OP-09 (Fig. 3). According to M-AMBI values, macrofauna was impacted and the benthic environment was damaged at OP–01, OP–02, and OP–03 stations.

In winter 2008, there were a total of 5511 individuals/m^2 and 11 species in benthic macrofauna at OP-01 station. There were 2711 individuals/m^2 of *C. capitata* indicator species, 1200 *Capitella* sp. individuals/m^2, 311 individuals/m^2 of *H. filliformis*, and 44 individuals/m^2 of *Notamastus sp*. There were 44 individuals/m^2 and 1 species, 44 individuals/m^2 of Capitellidae at OP-02 station. At OP-03 station, there were 311 individuals/m^2 and 3 species in total and, of indicator species, 222 individuals/m^2 of *H. filliformis*, and44 individuals/m^2 of Capitellids. There were 1111.1 individuals/m^2 and 6 species in total and, of indicator species, 222 individuals/m^2 Capitellids, 622 individuals/m^2 *H. filliformis* and 89 individuals/m^2 *Abra alba* at OP-04 station. According to Bray-Curtis similarity analysis of species diversity between stations in winter, maximum similarity was found at 69% between reference station and OP-08 (Fig 3). According to M-AMBI values, macrofaunawere impacted and the benthic environment was damaged at OP–01, OP–02, OP–03, OP-04 stations, and the ecological quality was moderate, poor, bad, and moderate, respectively.

In spring 2008, there were 489 individuals/m^2 and 4 species in total, and 133 individuals/m^2' *Capitellides,* 222 individuals/m^2 *Heteromastus filliformis, and* 44 individuals/m^2' *Abra Alba* as indicator species in benthic macrofauna at OP-04 station. According to Bray-Curtis similarity analysis of species diversity between stations in winter, maximum similarity was found at 53% between reference station and OP-08 (Fig. 3). According to the assessment made by M-AMBI values, macrofauna were impacted, the benthic environment was damaged, and ecological quality was at a very low level at OP–01, OP–02, OP–03, OP-04 stations.

In autumn 2008, there were 133 individuals/m^2 and 4 species in total in benthic macrofauna at OP-01 station. There were 844 individuals/m^2 indicator species of *C. capitata*, 133 individuals/m^2 *Capitella* sp., and 311 individuals/m^2 *H. filliformis*. There were 668 individuals/m^2 and 4 species in total and 89 individuals/m^2 of *C. capitata* and 400 individuals/m^2 *H. filliformis* as indicator species at OP-02 station. There were 222 indivduals/m^2 and 3 species in total, and 133 individuals/m^2 *H. filliformis* as indicator species at OP-03 station. There were 577 individuals/m^2 and 1 species in total and 578 pieces/m^2 *C. capitata* as indicator species at OP-04 station. According to Bray-Curtis similarity analysis of species diversity between stations in autumn, maximum similarity was found to be 75.41% between reference station and OP-08 (Fig. 4). According to M-AMBI values, macrofauna was affected at OP-04 and the benthic environment was damaged at OP-03 and OP-10 stations.

In winter 2009, there were 89 pieces individual/m^2 and 2 species in total in benthic macrofauna at OP-01 station. There were 44 pieces/m^2 *C. capitata* and 44 individuals/m^2 *H. filliformis* as indicator species. There were 222 individuals/m^2

and3 speciesin total at OP-02 station and 89 pieces/m^2 *H. filliformis* as indicator species. At OP-03 station, there were 133 individuals/m^2 and 2 species in total, and 86 individuals/m^2 *H. filliformis* as indicator species. According to Bray-Curtis similarity analysis of species diversity between stations in winter, maximum similarity was found at 20.42% except reference station, OP-06 and OP-07(Fig.4).According to M-AMBI values, benthic habitat was adversely affected by fish farming activities at OP-01, OP-03, OP-04 stations under the cages and the macrofauna were weakly affected at site number 2 and coastal station OP-10. In spring 2009, there were 89 individuals/m^2 and 2 species in total in benthic fauna atOP-01 station. There were 44 individuals/m^2 *H. filliformis* as indicator species. At OP-02 station, there were 444 individuals/m^2 and 2 species in total, and 89 individuals/m^2 *C. capitata* and 356 individuals/m^2 *Notamastus sp*. as indicator species. At OP-03 station, there were 267 individuals/m^2 and 3 species in total; and 133 individuals/m^2 *H. filliformis* and 44 pieces/m^2 *Notamastus sp*. as indicator species. At OP-04 station, there were 44 individuals/m^2 in total. According to Bray-Curtis similarity analysis of species diversity between stations in spring, reference station was 75.29% similar to OP-09. According to M-AMBI values, macrofauna was distortedat OP-02, OP-04, OP-05 stations under the cage and it was weak at OP-01 and OP-03 stations.

Table 5: H', AMBI, M-AMBI values of the stations in Ordu-Perşembe fish farming area and their ecological quality status.

Season	Index	OP-REF	OP-01	OP-02	OP-03	OP-04	OP-05	OP-06	OP-07	OP-08	OP-09	OP-10
2007 summer	H'	2,740	0,918	1,842	1,585	2,236	2,252	0,000	0,722	2,778	2,041	1,842
	AMBI	1,100	3,000	2,786	1,000	1,929	0,750	0,500	0,300	2,029	2,443	2,357
	M-AMBI	0,937	0,335	0,543	0,528	0,674	0,729	0,317	0,434	0,864	0,670	0,482
	Ecological status	high	poor	moderate	moderate	good	good	high	moderate	high	Good	moderate
2007 autumn	H'	2,500	1,270	0,000	0,500	2,000	1,710	2,890	1,660	2,280	3,010	0,810
	AMBI	3,060	4,977	6,000	6,000	3,660	2,382	1,408	0,429	3,136	1,929	1,125
	M-AMBI	0,670	0,324	0,289	0,381	0,621	0,489	0,906	0,567	0,600	0,883	0,370
	Ecological status	good	poor	poor	poor	good	moderate	high	good	good	High	poor
2008 winter	H'	2,170	2,126	0,811	0,000	1,357	2,188	2,747	2,412	2,940	2,606	2,000
	AMBI	1,541	5,464	4,500	7,000	3,750	3,440	1,941	1,625	2,487	2,842	1,125
	Continue table1:											
	M-AMBI	0,634	0,439	0,237	0,000	0,544	0,581	0,836	0,847	0,926	0,631	0,612
	Ecological status	good	moderate	poor	bad	moderate	good	good	good	high	good	good
2008 spring	H'	3,100	0,000	0,000	0,000	1,630	1,370	2,110	1,470	2,050	2,250	1,350
	AMBI	2,647	7,000	7,000	6,000	3,938	3,300	1,778	1,531	1,851	1,688	4,777
	M-AMBI	0,877	1,000	1,000	0,315	0,465	0,393	0,731	0,632	0,684	0,642	0,322
	Ecological status	good	bad	bad	bad	moderate	moderate	good	good	good	good	poor
2008 summer	H'	1,826	1,035	2,662	2,242	2,452	2,455	2,104	1,918	2,613	1,595	1,825
	AMBI	2,963	3,236	4,789	3,826	3,780	4,881	1,672	2,515	3,367	4,071	5,000
	M-AMBI	0,899	0,411	0,675	0,663	0,803	0,659	0,794	0,751	0,812	0,649	0,525
	Ecological status	good	moderate	good	good	high	good	high	good	high	good	moderate
2008 autumn	H'	1,284	1,403	1,555	1,371	0,000	1,880	2,035	2,180	2,014	1,664	0,592
	AMBI	4,731	5,638	4,500	4,125	6,000	4,125	0,656	1,588	3,971	3,500	4,500
	M-AMBI	0,578	0,460	0,578	0,486	0,017	0,669	0,978	0,897	0,825	0,607	0,243
	Ecological status	moderate	moderate	good	moderate	bad	good	high	high	high	moderate	poor
2009 winter	H'	2,585	1,000	1,522	0,918	0,000	2,180	1,575	2,144	2,118	2,372	1,000
	AMBI	1,250	5,250	3,900	4,000	7,000	4,200	0,796	1,755	4,286	3,600	5,250
	M-AMBI	0,638	0,191	0,374	0,203	1,000	0,597	0,786	0,920	0,584	0,726	0,223
	Ecological status	good	bad	poor	poor	bad	moderate	good	high	good	good	bad
2009 spring	H'	2,218	1,000	0,722	1,459	0,000	0,000	1,314	1,627	0,774	1,113	1,685
	AMBI	3,326	2,250	3,600	4,125	1,500	1,500	0,255	0,259	3,000	3,643	3,429
	M-AMBI	0,886	0,253	0,191	0,446	0,083	0,083	0,727	0,814	0,486	0,510	0,830
	Ecological status	good	poor	bad	moderate	bad	bad	good	good	moderate	moderate	moderate

The effect of rearing activities in the region on benthic area was observed to be low by the studied index values at Trabzon-Yomrafish farming stations between summer 2007 and spring 2009 (Table 6).

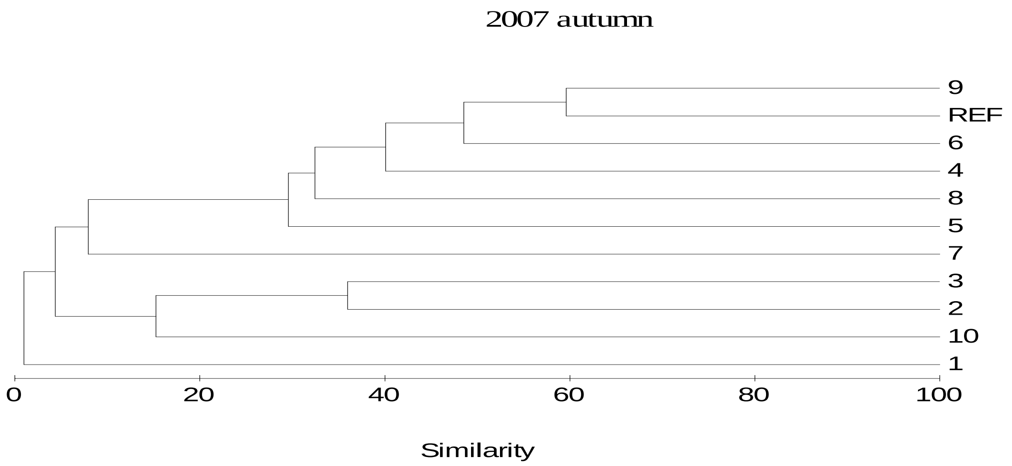
Table 6: H’, AMBI, M-AMBI values of the stations in Trabzon-Yomra farming area and their ecological quality status.

Season	Index	TY-REF	TY-01	TY-02	TY-03	TY-04	TY-05	TY-06	TY-07	TY-08	TY-09	TY-10	TY-11
2007 summer	H'	1,892	2,482	0	1	2,5	2,5	2,131	2,199	2,5	0,619	0,918	2,459
	AMBI	1,385	2,045	1,5	0,75	2,063	1,962	1,588	1,255	1,962	1,269	4	2,125
	M-AMBI	0,787	0,743	1	0,857	0,422	0,803	0,718	0,943	0,572	0,294	0,802	0,605
	Ecological status	good	good	bad	high	good	good	good	good	good	poor	good	good
2007 autumn	H'	2,189	2,55	0	0	2,156	1,585	1,597	1,68	2,549	2,064	1,585	1,922
	AMBI	1,231	2,455	1,5	3	2,625	0,5	1,448	1,395	1,9	1,393	3	2,7
	M-AMBI	0,852	0,509	0,32	0,689	0,529	0,629	0,747	0,75	0,912	0,429	0,44	0,46
	Ecological status	good	moderate	moderate	good	moderate	good	good	good	good	moderate	moderate	moderate
2008 winter	H'	2,242	2,829	2,908	3,236	3,271	1,903	2,369	1,282	2,664	2,925	3,122	3,023
	AMBI	1,4	2,386	1,463	1,5	2,224	2,686	1,5	1,575	2,88	1,583	3,474	1,4
	M-AMBI	0,705	0,845	0,895	0,867	0,921	0,709	0,596	0,641	0,594	0,953	0,827	0,714
	Ecological status	good	high	high	high	high	good	good	good	good	high	high	good
2008 spring	H'	2,554	3,382	2,915	2,647	3,25	2,236	1,911	2,157	3,297	2,677	3,312	3,023
	AMBI	2,338	2,559	2,458	3,587	2,25	1,286	1,368	1,235	2,741	2,49	2,625	2,389
	M-AMBI	0,528	0,881	0,756	0,693	0,646	0,64	0,68	0,742	0,809	0,847	0,814	0,664
	Ecological status	good	high	good	good	good	good	good	good	high	high	high	good
2008 summer	H'	2,604	0,659	2,154	1,585	1,967	1,55	1,627	0,855	2,364	2,478	2,845	2,699
	AMBI	3,05	2,875	3,125	3,833	2,382	2,382	2,792	0,688	3,564	3,033	3,167	2,6
	M-AMBI	0,9	0,37	0,631	0,622	0,598	0,544	0,59	0,567	0,631	0,758	0,7	0,777
	Ecological status	high	poor	good	good	good	good	good	good	good	good	good	high
2008 autumn	H'	2,47	2,922	2,369	2,777	2,218	0,25	1,188	2,611	2,914	2,171	2,992	2,055
	AMBI	2,5	3	3,458	1,875	1,4	0	0,464	4,292	3,595	2,964	4,25	3,25
	M-AMBI	0,641	0,756	0,59	0,796	0,777	0,378	0,563	0,677	0,735	0,537	0,844	0,591
	Ecological status	good	good	good	high	high	poor	good	good	good	good	high	good
2009 winter	H'	2,927	3,178	3,156	1,918	2,334	3,1	1,339	1,833	2,552	3,096	1,608	2,752
	AMBI	2,036	1,679	1,986	3,333	1,16	1,428	1,318	0,583	2,333	2,05	2,219	1,69
	M-AMBI	0,781	0,889	0,819	0,573	0,763	0,957	0,607	0,669	0,714	0,788	0,553	0,715
	Ecological status	high	high	high	good	good	high	good	good	good	high	good	good
2009 spring	H'	1,946	1,585	1,491	1,585	1,689	2,233	1,048	1,658	1,42	2,163	1,5	1,522
	AMBI	3,725	4,833	3,833	2,833	1,357	0,443	0,389	2,833	1,25	3,583	5,167	6,167
	M-AMBI	0,889	0,701	0,715	0,701	0,738	0,946	0,717	0,769	0,632	0,815	0,61	0,584
	Ecological status	good	good	good	good	good	high	good	good	good	good	good	good

The degree of impact for the stations at Rize cage aquaculture is given in Table 7. It is recognized that the degree of impact for the stations under the influence of cage aquaculture between summer 2007 and spring 2009 was low, if any. The effect was concentrated on the station no RM-02; however, it was little. At the same time, coastal stations RM-10, RM-11 were of the lowest ecological quality in 2008 spring season.

Table7: H', AMBI, M-AMBI values of the stations in Rize-Central farming area and their ecological quality status.

Season	Index	RM-REF	RM-01	RM-02	RM-03	RM-04	RM-05	RM-06	RM-07	RM-08	RM-09	RM-10	RM-11
2007 summer	H'	2,005	2,250	1,500	2,222	2,547	2,722	1,753	0,993	1,854	0,544	2,000	1,585
	AMBI	1,773	3,000	2,250	1,909	2,929	1,050	2,167	0,094	0,462	0,375	1,125	1,000
	M-AMBI	0,690	0,658	0,513	0,755	0,834	0,906	0,593	0,605	0,783	0,444	0,677	0,587
	Ecological status	good	good	moderate	good	good	good	good	good	good	Moderate	good	good
2007 autumn	H'	2,840	1,804	1,780	2,092	2,249	2,953	2,299	3,072	2,236	1,522	0,000	0,000
	AMBI	0,776	1,432	0,618	0,281	1,370	1,754	1,147	1,352	1,714	0,600	0,000	0,000
	M-AMBI	0,613	0,636	0,738	0,686	0,879	0,777	0,910	0,614	0,563	0,878	0,397	0,397
	Ecological status	good	good	good	good	good	good	good	good	good	good	good	good
2008 winter	H'	2,679	2,769	2,147	2,772	2,420	2,978	2,481	2,611	2,988	1,995	1,563	1,585
	AMBI	1,700	2,977	0,391	0,447	3,115	3,056	1,944	1,442	0,798	0,611	1,269	2,500
	M-AMBI	0,776	0,758	0,814	0,972	0,666	0,755	0,717	0,761	0,931	0,852	0,627	0,448
	Ecological status	good	good	good	good	good	good	good	good	good	good	good	good
2008 spring	H'	3,016	2,968	2,275	0,621	2,278	2,676	2,583	2,833	1,871	2,350	0,612	1,216
	AMBI	1,062	3,677	0,386	0,068	4,441	3,188	1,432	3,450	1,829	0,214	1,355	0,000
	M-AMBI	0,846	0,862	0,478	0,725	0,765	0,788	0,791	0,756	0,799	0,924	0,392	0,486
	Ecological status	good	good	moderate	good	good	good	good	good	good	good	moderate	moderate
2008 summer	H'	2,522	1,669	1,354	1,525	2,622	2,156	2,552	2,059	2,174	1,463	1,815	1,461
	AMBI	1,250	2,167	0,037	0,057	2,563	1,500	1,429	1,333	3,100	0,071	0,030	0,048
	M-AMBI	0.81237	0.64977	0.61539	0.72326	0.846	0.70153	0.93218	0.69587	0.71935	0.67142	0.76336	0.67218
	Ecological status	good	good	good	good	good	good	good	good	good	good	good	good
2008 autumn	H'	2,341	2,906	1,691	1,077	2,881	2,978	2,904	2,703	2,550	2,023	0,855	2,252
	AMBI	1,125	2,05	0,217	0,078	2,03	2,019	1,98	2,06	1,63	1,07	0,2234	0,25
	M-AMBI	0.77433	0.87211	0.7488	0.65418	0.80957	0.8689	0.86262	0.76712	0.73683	0.60671	0.55325	0.70339
	Ecological status	good	high	good	good	good	high	high	good	good	good	good	good
2009 winter	H'	2,602	2,602	1,976	1,345	2,020	2,606	2,859	2,044	1,709	2,089	1,997	2,549
	AMBI	1,5	1,765	0,307	0,211	3,957	2,12	3,6	3	0,393	0,3	1,05	3,6
	M-AMBI	0.79848	0.81677	0.80151	0.72096	0.73506	0.88826	0.86182	0.66269	0.68587	0.74057	0.69764	0.7059
	Ecological status	good	good	good	good	good	good	good	good	good	good	good	good
2009 spring	H'	2,412	2,808	2,162	1,936	2,433	2,573	2,547	2,881	2,237	2,864	2,649	2,760
	AMBI	0,416	2,07	0,937	0,281	1,8	1,808	0,986	1,891	3,8	2,357	1,363	2,836
	M-AMBI	0.74759	0.83627	0.70843	0.65172	0.6786	0.75779	0.79707	0.75274	0.56961	0.7673	0.72944	0.85165
	Ecological status	good	good	good	good	good	good	good	good	good	good	good	good



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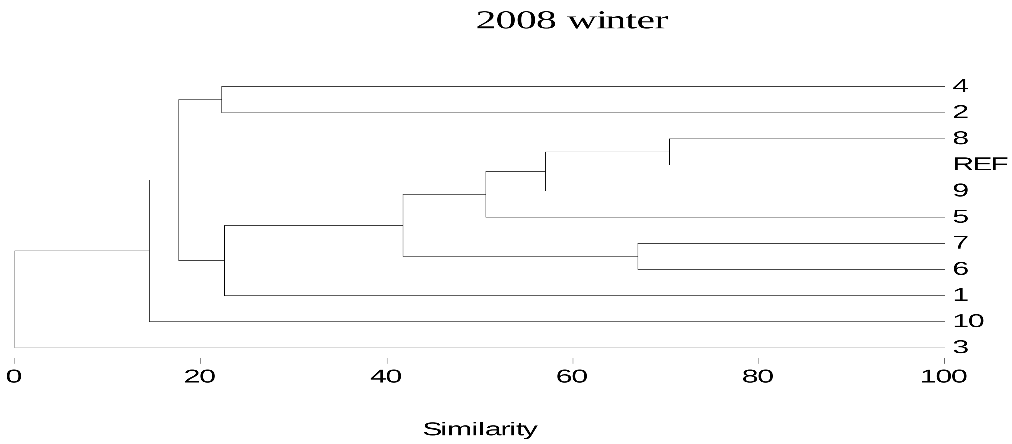

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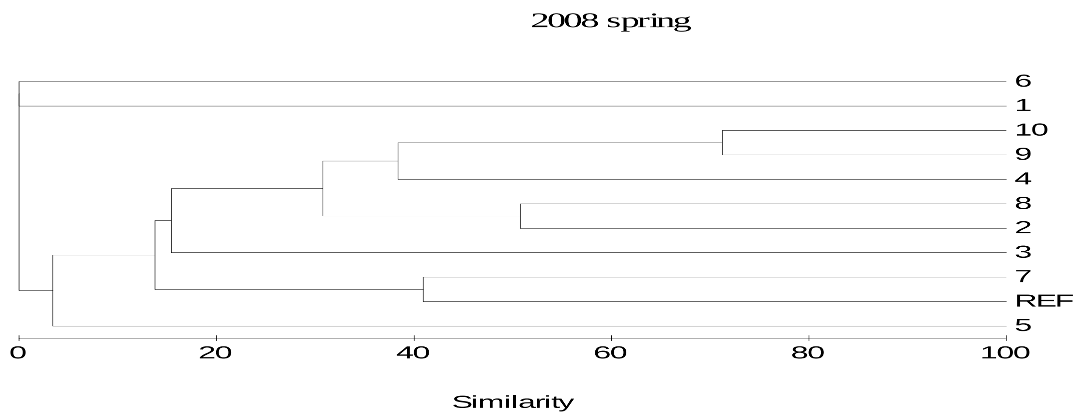

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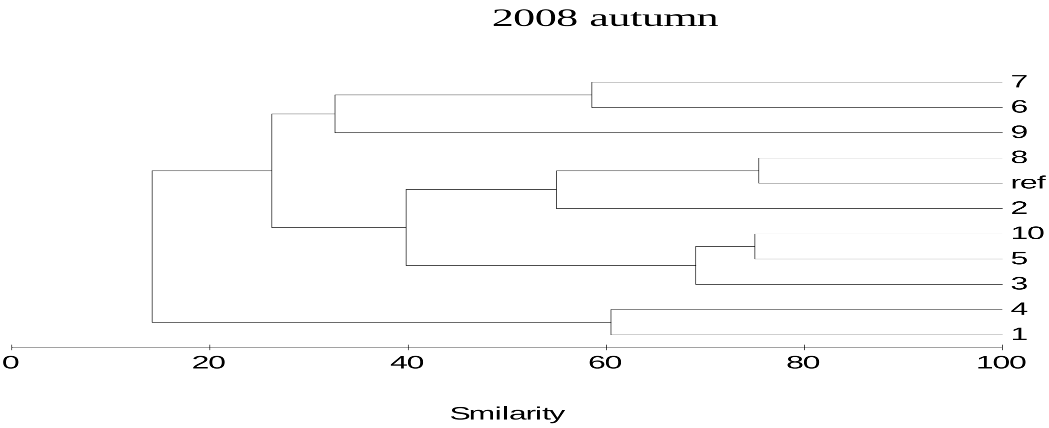
Figure 3: Bray-Curtis similarity analysis of Ordu –Perşembe fishfarming stations (A: 2007 autumn, B: 2008 winter, C: 2008 spring).



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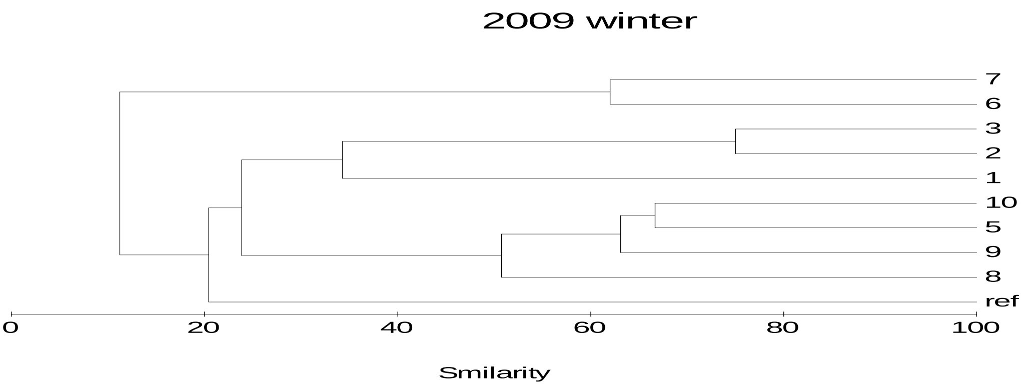

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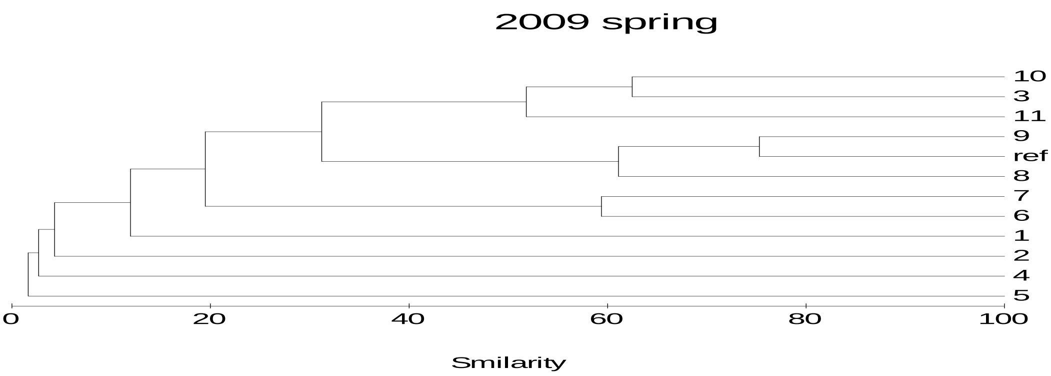

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Figure 4: Bray-Curtis similarity analysis of Ordu –Perşembe fishfarming stations (A: 2008 autumn, B: 2009 winter, C: 2009 spring).

Discussion

The results of the present study clearly illustrated that the impact of benthos quality reached the maximum level in autumn, winter, and spring when aquaculture farming activities increase at Ordu-Persembe aquaculture farming facilities, and that it decreased during the summer months. Similar results on benthos quality in periods of high farming activities were also reported in previous studies (Karakassis *et al*., 2000; Borja *et al.*, 2009). That the opportunistic species of *C. capitata*, *Capitella* sp. and *H. filiformis* were extensively found under the cages supported by the reports of researchers (Pearson and Rosenberg, 1978; Yücel-Gier *et al*., 2007) was also observed in the present study.The movement of water and suspended solid materials occurred in the direction parallel to the current in the region (the occurrence of water movement and suspended particular matters throughout the same direction of the current in study area), resulted in a significant coastal impact in all seasons.It was observed that the benthic habitats under the fish cages were affect edin creasingly in association with the direction of the flow, sediment type, the amount of stocked fish, and organic carbon. On the other hand, when the effect decreased around the cages, species diversity increased away from the cages. The effect was determined at coastal stations, especially in spring.The greater benthos effect at Ordu–Perşembe station is thought to stem from the fact that the farming activities have continued there both in winter and summer throughout the year for many years.

Trabzon-Yomra aquaculture farming business has been operating just for ten years; because of this, it had slight effect on the benthic ecosystem. The direction and intensity of the water current, distance from the shore, sufficient water depth are main factors which affect the benthic ecosystem. Seasonal differences in the direction of the flow in Yomra caused the waste of the cages disperse and helped reduce the pollution build-up. It was noticed that the benthic habitats were affected at the central station of the cages and this effect decreased and diversity of species increased moving away from the cages. These findings are supported by other studies, as well. Karakassis *et al*., (1999), Vita and Marin (2007) and Borja *et al*., (2009) reported that the diversity and number of species were the lowest at the stations under the cages but they increased markedly as moved away from the cages. In addition, it is thought that coastal impact (with the increased terrestrial inputs due to the rainfall) affects the benthic habitats more than fish farms in some seasons. In this study, it was observed that although there were differences between the stations at Perşembe and Yomra facilities. AMBI values were observed to be in general higher under the cages but lower away from the cage systems. Borja *et al*., (2009) reported that AMBI values decreased away from the cages in many farms, which indicated the idea of increased benthic environment quality.

Diversity index values at Rize farming facility were found higher at RM-01 under-cage station, indicating that species richness increased contrary to the expectations. The facility in the region has been in operation for only five years and can be considered as new. RM-01 station is the one, which enriched in the region in terms of organic matter accumulation.This enrichment is the main reason for the increase in opportunistic species at this station. In general, accumulation of organic matter in aquaculture activity in the region was observed to be very little. The main reason for the accumulation not reaching high values depending on the years is that pollutants from the cages have an effect on reducing the burden of sediment accumulation due to seasonal variation in the direction of the current inthe region.The area of the fish farm in the region is under intense influence of domestic waste in central Rize. The most obvious evidence of this is the low ecological quality of the coastal stations and relatively fewer species diversity compated to other stations.

Unlike Ordu, organic carbon results showing a temporal increase at Trabzon stations were also seen at reference station, which indicated that there may be input of pollutants from other sources (such as domestic input) or there might be some entry due to the current.

The fact that the benthic environment was least affected by the polluting effect of fish farms may have been possible with the use of today’s technological and scientific research results. As a result of research studies carried out, sustainable fish farming using less environmentally harmful feed, materials and chemicals, and allowing self-purification of the environment and with appropriate site selection can have a positive contribution in economic, ecological, and social aspects.

In order to observe the changes on the benthic environment by cage aquaculture businesses, it is vitally important to know the state of organisms in the current region prior to aquaculture activities. The most effective way to reduce negative effects of farming system is to select suitable area to establish the cages. For the selection of the cage areas, it is necessary that the areas of cage culture farms be treated as a separate system and the size of every pollutant source and its effect on the system is determined. Fish farms placed in the wrongly located in unsuitable area, without required examinations, not only can cause a disruption in the marine ecosystem over time, but also can cause limits in the habitat capacities of many species and threat the environmental health as well. There are many criteria that should be taking into consideration (e.g. water quality, current velocity and direction, water exchange rate, depth, and sediment structure), which play important role in the selection of a good place for new aquaculture enterprise.

The present research is the first study, which makes contribution to our understanding of the functional role of the cage systems and their potential effects on the aquatic ecosystems along the South Eastern Black Sea. An understanding of functional role of cage systems is crucial to determine potential effects on the aquatic systems and adjacent areas. Results of this work clearly illustrated that there is a need for further investigations at the region in order to reveal current ecological status. Besides, ecology of the area should be monitored regularly, for sustainable aquaculture farming. An effective management plan for the cage enterprises built after all appropriate research may give rise to a structure that can provide environmental, social and economic sustainability.

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