Menba Kastamonu Üniversitesi Su Ürünleri Fakültesi Dergisi
Menba Journal of Fisheries Faculty
ISSN 2147-2254 | e-ISSN: 2667-8659

Menba Kastamonu Üniversitesi Su Ürünleri Fakültesi Dergisi 2022; 8(2): 59-68 Araştırma Makalesi/Research Article

The Assessment of Diversity of Benthic Macroinvertebrates of a Stream from the Eastern Black Sea Basin, Turkey

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Article Info

Received: 13/05/2022
Accepted: 14/11/2022

Keywords:
- Running water
- Benthic macroinvertebrates
- Water quality parameters
- Diversity index
- Biotic index

Abstract

This research was aimed to assess the diversity of benthic macroinvertebrates and some physico-chemical water parameters of Fırtına Stream of East Blacksea Basın and carried out between November 2014 and August 2015. Benthic and water samples were taken for one year from selected six stations seasonally (November-February-May-August) from the upstream to the flowing to the sea. Water temperature, pH, dissolved oxygen and conductivity were measured *in situ*. The results were evaluated according to Turkish Surface Water Quality Regulation and Fırtına Stream had high water quality. The benthic macroinvertebrates consisted of *Ecydonorous* (Ephemeroptera, Heptaginiidae), *Sericostoma* (Trichoptera, Sericostomatidae), *Tipula*, *Tabanus* ve *Chironomus* (Diptera, Tipulidae, Tabanidae, Chironomidae) from Insecta class. Some of these organisms were seen in unpolluted and some of them in slightly polluted waters. The proportionally distribution of the organisms were as Sericostomatidae (83%), Tipulidae (14%), Heptaganiidae (2%) and Tabanidae (1%), respectively. Diversity index (H) value was found to be low between 0 and 0.68. Biotic index (BMWP) score was also low and in the Class IV category (polluted water).

Atıf bilgisi/Cite as: Cılız S., Kırkağaç M. (2022). The assessment of diversity of benthic macroinvertebrates of a stream from the eastern Black sea basin, Turkey. Menba Journal of Fisheries Faculty, 8(2), 59-68

INTRODUCTION

In aquatic systems, pollution cause physical, chemical and biological changes in the receiving environment. Benthic macroinvertebrates colonized on the stream substrate with their relatively long life cycles, are widely used in river quality studies, as they react rapidly by showing sensitivity under different stress conditions and are indicators in local regions because of their limited movements (Hawkes, 1979: Cummins, 1994; Richards et al., 1997; Midlen & Redding, 2000).

Fırtına Stream is one of the 26 main catchment watershed is located in the Eastern Black Sea Basin in Turkey as a tourism region has 68 km in length, It is formed by the merging of the streams on the slopes of the Kaçkar Mountains facing the Black Sea and it flows into the Black Sea. While the stream is fed by spring rainfalls and the glaciers in the Kaçkar Mountains during summer periods, the flow rate decreases significantly in the autumn and winter months. Black Sea trout (*Salmo trutta labrax*) and rainbow trout (*Onchoryncus mykiss*) are cultured a total of 775.5 tons / year in Rize Province and 690 tons of this amount is obtained from 19 fish farms on Fırtına Stream (Kurtoğlu, 2013). Besides this, local administrations in settlements on the Fırtına Stream leave their wastes to the stream where as the most important entrance of the Black Sea trout for spawning. So, Fırtına Stream is one of the most important rivers in the region to be protected against external factors that will affect the reproduction migration of Black Sea trout (Çelikkale et al., 1999; Aydın & Yandı, 2002; Tabak et al., 2002). There is only one study on benthic macroinvertebrates in Fırtına Stream, with sampling twice, in the summer period in July 2006 and 2008 (Kazancı et al.,2010).

In this research, it is aimed to assess the diversity of benthic macroinvertebrates and water quality of the Fırtına Stream with the samples taken seasonally for a year, to reveal the condition of the stream by comparing it with the previous studies.

MATERIAL AND METHODS

Fırtına Stream is located in Rize province, it is close to Ardeşen district, and in terms of geographical location; it is at the coordinates of latitude 41°11'17' 'N and longitude 40° 57'50 " E (Figure1). Fırtına Stream is the longest stream in the region with a length of 68 km and a drainage area of 798.7 km^2. Annual average rainfall in the valley is 1497.6 mm/m^2. Its average flow is 28.4 m^3/sec and it carries more water than most of the rivers in Turkey (Tabak et al. 2002).

Figure 1.The location of Fırtına Stream and the stations

This study was carried out between November 2013 and August 2014, with samples taken from a total of 6 stations (Figure 1). The first station was close to the source and as far away from environmental effects as possible (station 1), the others were close to the settlements and trout facilities (station 2 and station 3) and the last station (station 6) was on the point where the stream flows to the sea. The distances between the stations were about 10 km. Benthos and water samples were taken 4 times in a year as November-February-May-August, respectively. Water temperature (^{0}C), pH, electrical conductivity (µs/cm) and dissolved oxygen (mg/l) values were measured *in-situ* and evaluated according to Turkey Surface Water Quality Regulation (Anonymous 2004). Chlorophyll *a* was determined in the laboratory according to APHA (1998).

The benthic samples collected from the stations in triplicate by a hand-net was filtered through a series of sieves varying between 250 and 3000 µm mesh size, and the collected benthic macroinvertebrates were stored in 4% formaldehyde in sample containers. The benthic macroinvertebrates were identified at family and genus levels under binocular and stereo microscopes according to Edmondson (1959), Macan (1975), Grant (2001), Thorp & Rogers (2011) and counted. The results were given as abundance per unit area (individual/m^2).

Shannon-Weaver diversity index was used to evaluate the diversity of benthic macroinvertebrates. Therefore, the number of species (richness-S), the equibility of the abundance of families (E) and the total number of organisms (abundance-N) were determined (Zischke et al., 1992).

Shannon-Weaver Index (H) = $-\Sigma$ Ni / N log$_2$Ni / N (1)

H = index value

N = total number of individuals of all species collected

Ni = i. indicates the total number of individuals belonging to the species.

Evenness index (E); E = H / ln S is calculated from the equation.

Here; H = Shannon-Weaver Index, S = Species richness

BMWP score of the stream was determined for assesing the biological quality of Fırtına Stream as giving scores to macroinvertebrate families depending on their sensitivity to physicochemical and environmental changes (Metcalfe-Smith, 1994; Anonymous, 2004). For this research, BMWP scores and water quality classes that were determined for benthic macroinvertebrates of Turkish running waters ecosystems were used (Kazancı et al., 2016) (Table 1 and Table 2).

Table 1. Table 1. TR-BMWP, family list (Kazancı et al. 2016)

Order	**Family**	**Score**
Trichoptera	Sericostomatidae	10
Ephemeroptera	Heptageniidae	8
Diptera	Tipulidae	5

Table 2. TR-BMWP scores and their corresponding quality classes

TR-BMWP Score	Category	Water Quality Classes	Interpretation
>100	Very good	1	Unpolluted/Unimpacted
71-100	Good	2	Clean but slightly polluted/impacted
41-70	Moderate	3	Moderately impacted
11-40	Poor	4	Polluted/impacted
0-10	Very poor	5	Heavily polluted

Statistical analysis were carried out by using SPSS 11.5 Statistic Program.Variance analysis (One way-ANOVA), Duncan multiple range test were computed to evaluate the differences of in abundance values of benthic macroinvertebrates between stations and months (Kesici & Kocabaş 2007).

RESULTS AND DISCUSSION

Benthic macroinvertebrate of Fırtına Stream were identified as *Ecydonorous* (order-Ephemeroptera, family-Heptaginiidae), *Sericostoma* (order-Trichoptera, family Sericostomatidae), *Tipula, Tabanus* and *Chironomus* (order-Diptera, families Tipulidae, Tabanidae and Chironomidae respectively) (Table 3).

Table 3. Benthic macroinvertebrates of Fırtına Stream

Phylum-Arthropoda			
Class	**Order**	**Family**	**Genus**
Insecta	Ephemeroptera	Heptageniidae	*Ecdyonorous*
	Trichoptera	Sericostomatidae	*Sericostoma*
	Diptera	Tipulidae	*Tipula*
		Tabanidae	*Tabanus*
		Chironomidae	*Chironomus*

Benthic macroinvertebrates functional feeding groups consisted of shredders (Sericostomatidae), collectors (Chironomidae), scrapers (Heptaganiidae) and predators (Tipulidae, Tabanidae). During the study, the shredder group (Sericostomatidae) constituted the largest proportion as 75% in functional feeding groups which fed on particulate allochthonous organic material and faecal pellets on adults (Figure 2).

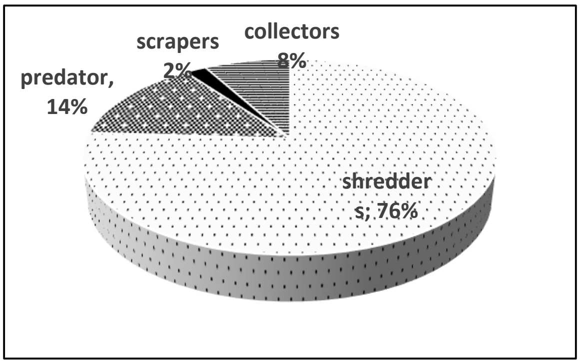

Figure 2. The proportions of functional feeding groups of Fırtına Stream (%)

The differences in the abundances of benthic macroinvertebrates of Fırtına Stream according to the stations and seasons were found to be statistically significant ($p < 0.05$) (Table 4). Sericostomatidae members are organisms that are sensitive to environmental effects, mostly found in upper part of the streams that is cold and includes high-dissolved oxygen, and their abundances were higher in the first station, especially in autumn samples than other stations. Members of the Tipulidae from Diptera show low tolerance to pollution. This makes them indicator organisms in waters with good water quality, while members of the Tabanidae family from the same order show moderate tolerance in the same conditions. In this study, members of Chironomidae and Tabanidae families with moderate pollution tolerance (Hawkes 1979) were found only in 1st station, but abundance values were low in autumn and winter. Ephemeroptera members, which are indicators of fast flowing and clean waters, were found to be low in abundance and were found only in autumn. Kırkağaç et al. (2004) investigated the effects of five trout farms on the macroinvertebrate communities on the Karasu Stream (Bozüyük), and found Tubificidae and Chironomidae members with high abundances as indicators of organic pollution, at all stations. In the 2nd and 3th stations which were the inlet and outlet of the trout farm on Fırtına Stream, no difference was found in macroinvertebrate diversity and abundances. However, the identified species in those stations were relatively intolerant to pollution. Although relatively tolerant species were found in this study, their abundances are low. It is thought that heavy rainfall and floods may be the factor in the low abundance of those tolerant organisms.

A total of 36 families and 2080 individuals in samples taken from 10 stations, only in July of years 2006 and 2008 in Fırtına Stream were identified by Başören and Kazancı (2016). Among the families identified in benthic macroinvertebrates, the most common ones were Heptaganidae (30%), Baetidae (15%), Perlidae (11%), Blephariceridae (10%) and Hydropyschidae (9%), respectively. In this research, it was as Sericostomatidae (83%), Tipulidae (14%), Heptaganiidae (2%) and Tabanidae (1%) and the Heptaganiidae family was determined only in autumn. The results regarding the number of families, abundances and proportional distribution of benthic macroinvertebrates of this research are not similar to the results of Başören and Kazancı (2016). It is thought that temporal, seasonal and environmental factors caused the differences in the results.

Table 4. Average abundance values of benthic macroinvertebrates in Fırtına Stream, according to seasons and stations, individual/m^2 (n=3) and proportional changes of benthic macroinvertebrates groups in seasons according to stations (%)

Season	Organism Groups	Stations						
		1	2	3	4	5	6	Total
Autumn	***Trichoptera***	*83.96%*	*3.05%*	*0.76%*	-	*2.29%*		
	Sericostomatidae	110	4	1	-	3	-	118
	Diptera	*2.29%*	*0.75%*	*2.27%*	*1.52%*			
	Tipulidae	-	1	3	2	-	-	6
	Tabanidae	3	-	-	-	-	-	3
	Ephemeroptera	*1.52%*	-	-	*1.52%*	-		
	Heptageniidae	2	-	-	2	-	-	4
	Total abundance	115±5A*a**	5±1Bb	4±1Cc	4±1Bb	3±1Bb	-	131
Winter	***Trichoptera***	*12.50%*	*18.75%*	*6.25%*	*2.08%*	*8.33%*	*8.33%*	
	Sericostomatidae	6	9	3	1	4	4	27
	Diptera	*2.08%*	*8.33%*	*12.5%*	*12.5%*	*6.25%*	*2.08%*	
	Tipulidae	-	4	6	6	3	1	20
	Chironomidae	1	-	-	-	-	-	1
	Total abundance	7±1Bcb	13±2Aa	9±1Bb	7±2Abc	7±1Abc	5±1Bc	48
Spring	***Trichoptera***	-	*6.89%*	*10.34%*	*13.79%*	*3.44%*		
	Sericostomatidae	-	2	3	4	1	-	10
	Diptera	*6.89%*	*3.44%*	-	-	*3.44%*	-	
	Tipulidae	2	1	-	-	-	-	3
	Chironomidae	-	-	-	-	1	15	16
	Total abundance	2±0Cd	3±1Cc	3±1Cc	4±1Bb	2±0 Cd	15±1Aa	29
Summer	***Trichoptera***	*15%*	*5%*	*62.50%*	-	*2.5%*		
	Sericostomatidae	6	2	25	-	1	-	34
	Diptera	-	-	-	*10%*	*5%*		
	Tipulidae	-	-	-	2	1	-	3
	Chironomidae	-	-	-	2	1	-	3
	Total abundance	6±1Bb	2±1Ce	25±5Aa	4±1Bc	3±1Bd	-	40

** Mean values with different small letters in the same line is statistically significant ($p < 0.05$).
* Mean values with different capital letters in the same column is statistically significant ($p<0.05$).

Shannon Wiener index (H), species richness (S) and evenness index (E) values of Fırtına Stream were determined seasonally at the stations (Table 5). Species richness varied between 0 and 3 during the research. The H value, as the pollution level of the stream, ranged from 0 to 0.68. Stations were represented generally with one taxon except 2nd station in seasons. Therefore, the diversity was recorded only at 2nd station with 0.68. The lowest E value was detected in the 1st station in autumn. E values were generally found close to 1 at the stations during the research. This shows regular distributions of the abundances of the taxa in the stations.

Shannon Wiener index (H) value was generally higher at stations 4 and 5 compared to other stations. The distribution of taxa in winter was more homogeneous. The high Shannon Wiener index value is reported as an indicator of high water quality (Kazancı et al., 2010). However, it is stated that limited level of organic matter is an important factor in low macroinvertebrate diversity in high quality waters (Uyanık et al., 2005).

Table 5. Species richness (S) Shannon-Wiener Index (H) and equibility (E) values of benthic macroinvertebrates of Fırtına Stream

Season	**Index**	**Stations**					
		1	**2**	**3**	**4**	**5**	**6**
Autumn	S	3	2	2	2	1	
	H	0.20	0.5	0.56	0.6	0	
	E	0.18	0.72	0.81	1	0	
Winter	S	2	2	2	2	2	2
	H	0.41	0.61	0.68	0.41	0.68	0.50
	E	0.59	0.89	0.98	0.59	0.98	0.72
Spring	S	1	2	0	1	2	1
	H	0	0.63	-	0	0.66	0
	E	0	0.91	-	0	1	0
Summer	S	1	1	1	2	2	0
	H	0	0	0	0.6	0.6	-
	E	0	0	0	1	1	-

BMWP score values for macroinvertebrates of Fırtına Stream were evaluated according to Table 1. BMWP scores and taxon richness at the stations according to the seasons are given in Table 6. At the end of the research, the BMWP score varied between 17 and 29. The highest score was reached at 1st and 4th stations as 29 and 25, respectively. Taxon richness has been between 2 and 5. The highest taxon richness was determined in the 1st station. BMWP scores at stations according to seasons were not found to be generally high. The BMWP score range of Fırtına Stream (11-40) is considered as poor category according to Table 2.

Table 6. BMWP and N-taxa values of benthic macroinvertebrates at stations according to seasons in Fırtına Stream

Stations	**Biotic Index**	**Seasons**				**Annually**
		Autumn	**Winter**	**Spring**	**Summer**	
1	BMWP	22	12	5	10	29
	N-Taxa	3	2	1	1	5
2	BMWP	15	15	15	10	15
	N-Taxa	2	2	2	1	2
3	BMWP	15	15	10	10	17
	N-Taxa	2	2	1	1	2
4	BMWP	15	15	10	7	25
	N-Taxa	2	2	2	2	3
5	BMWP	10	15	12	17	17
	N-Taxa	1	2	1	2	3
6	BMWP	-	15	2	-	17
	N-Taxa	-	2	1	-	3

In the research, BMWP values varied between 15-29 and the water quality was determined as Class IV. According to BMWP scores (48-109) of Başören & Kazancı (2016), BMWP scores were found to be low due to the low species richness and their low abundances in this research. However, low macroinvertebrate diversity can also be seen in waters where there is little destruction and where competitive superior species dominate the resources (Ward & Tockner, 2001).

The composition of functional feeding groups in Fırtına Stream consisted of those fed with grinder (Sericostomatidae), collector (Chironomidae), scraper (Heptaganiidae) and predator (Tipulidae, Tabanidae). Among the benthic macroinvertebrates, no filterers have been found. Scrappers that use terrestrially coarse particulated organic materials as a food source and convert them into fine particulated and dissolved organic matter (Meyer & O'Hop, 1983). Sericostomatidae were encountered at 1st station in all seasons except spring and disappeared towards the downstream in Fırtına Stream. Savic et al. (2013) reported that grinders are found at a rate of 50% in the upstream and decrease in the downstream in the Nisava River of Eastern Serbia. Bonada et al. (2004) reported that Sericostomatidae members tolerate slight increases in ammonium, orthophosphate and suspended solids in water.

Chironomidae, one of the collectors fed with fine particulate organic matter which was transported to the downstreams is seen in the last two stations in spring and summer but their abundances were relatively low. Tomanova et al. (2006) reported that the mobility of scraper, predators and shredders were high due to searching for food actively or by exposing to flow there was a risk of drift in floating substrates, it is not very suitable for macroinvertebrates to use their feeding strategies in ecosystems where pollution is seen suddenly. On the contrary, these organism groups can adapted themselves and act as collectors just to eliminate the effect of the current. However, it has been declared that the amount of internal and external organic matter in running waters will determine the distribution and abundance of functional nutrition groups of benthic macroinvertebrates (Vannote et al., 1980). In this research, the flow rate of Fırtına Stream is high, and the distribution of organisms belonging to the feeding groups was found to be irregular with low abundances. However, it is thought that using functional feeding groups with sediment quality analyses and long term investigation should be done for ecological evaluation of Fırtına Stream.

The differences between the average water temperature, dissolved oxygen, electrical conductivity and pH values according to the seasons and stations were found to be statistically significant ($p<0.05$) (Figure 3). The differences between chlorophyll *a* concentrations at the stations according to seasons were found to be statistically significant ($p <0.05$) (Figure 4).

During the research in Fırtına Stream, the temperature values measured in this research are in the range of the values reported by Alemdağ (1993) and Alkan et al. (2013). However, the lowest value for the winter that has been reported was higher than the value measured in this research. It is reported that the very low water temperature in Fırtına Stream is due to the high altitude and the long stay of snow in this region (Akın, 2016). Since the average temperature during the research is below 25°C, Fırtına Stream is evaluated as "High Quality Water" class, which has the potential to be used as drinking water and trout can be grown according to the Surface Water Quality Regulation (Anonymous, 2004).

During the research in Fırtına Stream, the lowest dissolved oxygen values were measured in summer and the highest values were measured in winter. The values obtained from this research are similar to the dissolved oxygen values reported by Akın (2016). In this research, no decrease tendency in the average dissolved oxygen values from the first to the last station in general. It was reported by Başören and Kazancı (2016) that the dissolved oxygen concentrations varied between 7.6-10.8 mg/l at 10 stations in July 2006 and 2008 in Fırtına Stream and due to the dissolved oxygen concentration below 8 mg/l at some stations, the stations were classified as Class I and II according to the Surface Water Regulation. Gedik et al. (2010) reported that the average dissolved oxygen value was about 10.40 mg/l at the station where Fırtına Stream flows to the sea whereas the value was about 10.60 mg /l in this research. It is thought that the high flow rate of Fırtına Stream caused higher dissolved oxygen concentrations even in downstreams. However, dissolved oxygen values tended to decrease with increasing temperature values at the stations. Since the average dissolved oxygen value at the stations is above 8 mg/l, Fırtına Stream is in the "High Quality Water" class, according to the Surface Water Quality Regulation (Anonymous, 2004).

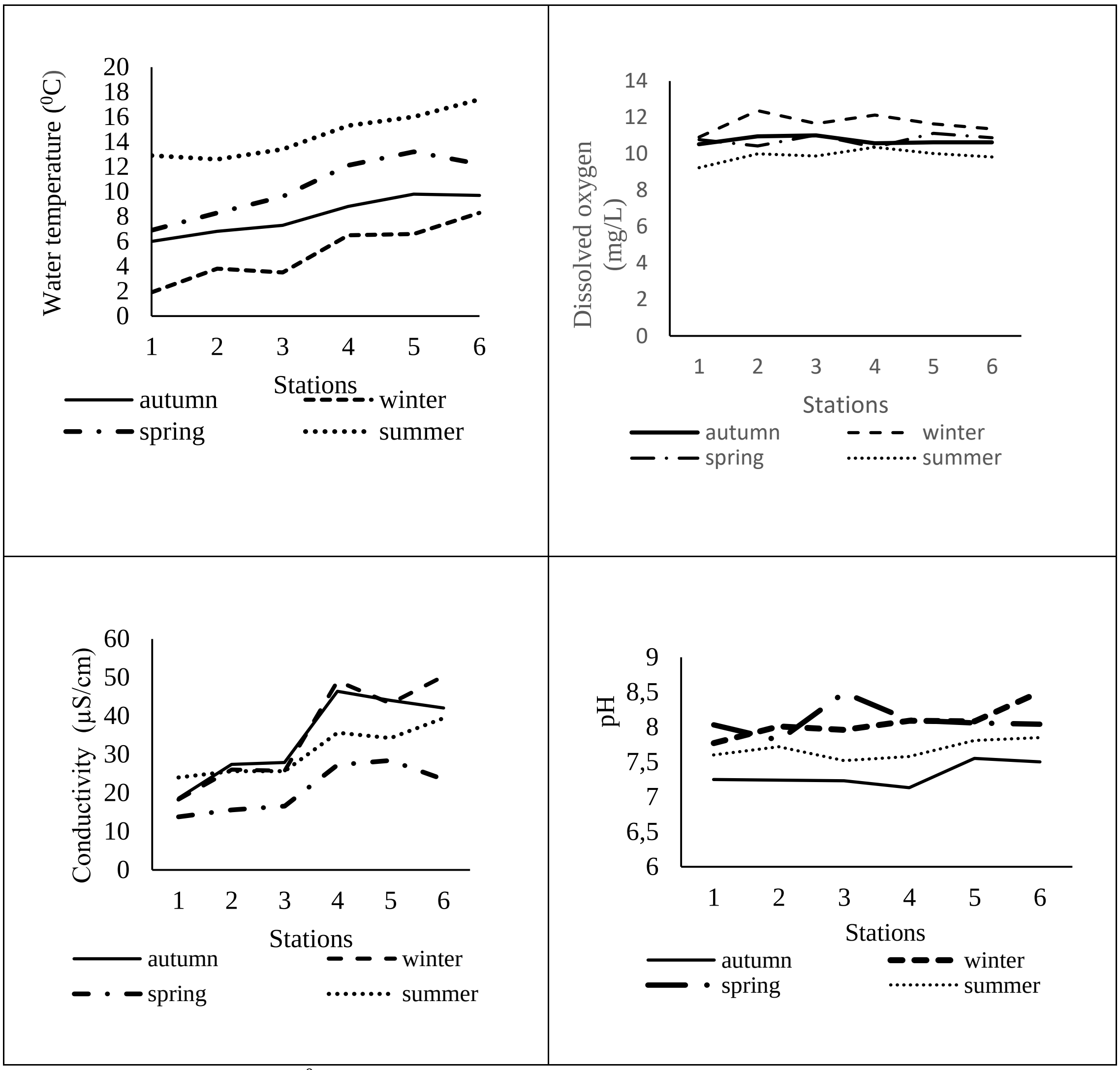

Figure 3.Average water temperature (^{0}C), dissolved oxygen (mg/ L), conductivity (µS / cm) and pH values of Fırtına Stream during the research

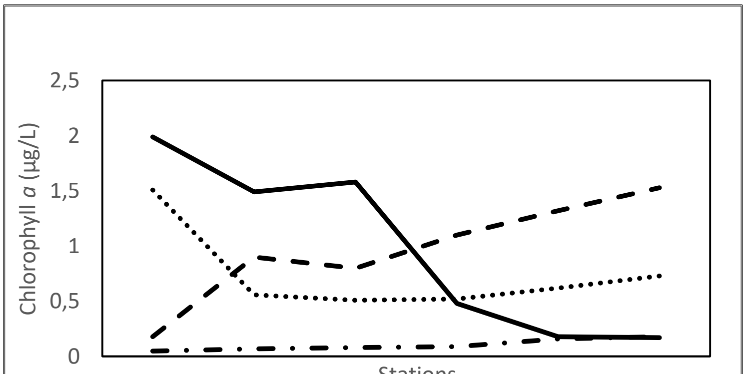

Figure 4. Average chlorophyll *a* (µg/L) concentrations of Fırtına Stream according to seasons at stations.

During the research, the highest pH values were measured in winter and summer. However, it has been observed that pH values at the last stations are generally higher than the first stations. It was reported from a previous study from Fırtına Stream that the pH values were high in the spring and summer months, which may be caused by the mixing of snow and rain water to the stream in autumn and winter months (Gedik et al., 2010). In this research, the pH values were higher than the previous investigations in Fırtına Stream (Alemdağ, 1993; Başören & Kazancı, 2010; Alkan et al., 2013). According to the Surface Water Quality Regulation (Anonymous, 2004), Fırtına Stream is a high quality water in terms of pH values.

During the research, the highest average conductivity values 50.30±1.00 µS/cm were measured at the last stations and the conductivity values of the stations increased in parallel with the increase in temperature. However, it has been reported that low ion concentration in running waters limits the flora and fauna in terms of species diversity and abundance (Allan, 1995). As similar to the highest value of conductivity in as declared (54.77 ± 1.04 µS/cm) by Gedik et al (2010) for Fırtına Stream that the stream is not rich in ions. However, it was reported that conductivity measurements are the best one in order to give the results regarding the level of pollution in water compared to other physical and chemical measurements, and in running waters which is under minimal pollution effects, the conductivity value is measured below 50 µS/cm (Wenner et al.2003). Since the average conductivity value of Fırtına Stream is below 50 µS / cm, it is in the high quality water class according to the Surface Water Quality Regulation (Anonymous, 2004).

During the research, the average chlorophyll *a* concentration varied between 0.05±0.02 and 1.99 ± 0.09 µg/l in Fırtına Stream. Chlorophyll *a* concentrations was generally tend to increase by the stations except autumn. Alkan et al. (2013) reported that the average chlorophyll *a* concentration in Fırtına Stream was below 1 µg/l. Phytoplankton biomass in the streams are low and downstreams are convenient for phytoplankton production because of high nutrient loading and low flows (Allan, 1995).

CONCLUSION

In this research, Fırtına Stream evaluated as 'High Quality Water' in the category Class I water quality according to Turkey Surface Water Quality Regulation. However, when evaluated in terms of benthic macroinvertebrates, Shannon Weiner index value found to be low. Likewise, the biotic index-BMWP score was also found to be low and it was evaluated in Class 4 water quality in the polluted water class. The water flow of Fırtına Stream is about 30 m^3/sec with the highest flow in the region among the streams and its slope is high. Because of this, chlorophyll *a* concentration is low and aquatic plants growing is poor. As indicated above, low macroinvertebrate diversity can also be seen in clean waters where competitive superior species dominate the resources. However, no filterers feeding group were found in the stream. Therefore, it is thought that the amount of organic matter in the environment may be a factor limiting species diversity and abundance.

The Fırtına Stream in the East Black Sea region is considered as one of the 200 ecological regions that have priority in protection in the world as biodiversity and ecological reservoir. The water quality of Fırtına Stream should be preserved for fish populations surviving. However, the applied diversity and biotic indices of benthic macroinvertebrate of the stream were found to be quite low according to Başören & Kazancı (2010). It is thought that this situation may arise from the sampling period, hydrology of water and terrestrial inputs. In recent years, the stream is under threat due to the increase in tourism facilities and road construction works in the region, Fırtına Stream should be monitored in long-term research in the case of benthic macroinvertebrates as indicators of water quality.

COMPLIANCE WITH ETHICAL STANDARDS

a)Authors' Contributions:

This article was derived from the PhD thesis of the first author. Second author supervisor of the doctorate thesis; statistical analyses and preparation of the article for publishing.

b) Conflict of Interest:

The author(s) declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper

c) Statement on the Welfare of Animals:

Not applicable

d) Statement of Human Rights:

Not applicable

ACKNOWLEDGEMENTS

We are grateful to Prof. Dr.Kadir Seyhan and Assoc. Prof. Nigar Alemdağ Alkan for supporting the research in field by supplying facilites for transporting and in laboratory for water quality analyses, respectively.

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