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The application of some biodiversity indices in the Tortum Stream, Erzurum, Turkey

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The aim of the present study was to investigate biodiversity index, dominancy index and equivalence index of diatom community in the Tortum Stream and its tributaries. Diatom samples were collected from nine stations on the main river and tributaries between July 2012 and May 2013. A total of 36 taxa of Bacillariophyceae were identified. Dominant species was *Cocconeis placentula* in all stations. Biodiversity index was lower on the upstream river than downstream and tributaries. Not only domestic and agriculture pollution but also dam construction and stone pit affected Tortum Stream negatively. In conclusion, species richness decreased while organic pollution tolerant species increased.

Key words: Diatom, biodiversity index, dominant index, evenness index, Tortum Stream.

INTRODUCTION

Benthic algal communities have developed in virtually all substrates that receive light, whether in small streams or large rivers. These communities have generated important part of water ecosystems due to their role in food chain and their quick response and direct to a lot of change in environmental parameters. Cell structure of diatom is directly connected to physicochemical parameters of water, so diatom is an indicator for identification of river water quality. Therefore, it is used as a tool to make comparison between aquatic ecosystems (Allan and Castillo, 2007).

The use of phytoplankton communities or other aquatic organisms as bioindicators goes back to very ancient times. For the first time, in 1954, benthic organisms were used as bioindicators by Patric due to their easy adaption to changes in the chemical and physical displacement (Thunmark, 1945; Nygaard, 1949; Lepistö and Rosenström, 1998).

In Turkey, the earliest study in which diatoms were used to evaluate the water quality changes was carried out by Kalyoncu and Barlas (1997) in which he gave more information about that study (saprobic index etc.). Organic pollution is usually closely related to enhance nutrient concentrations. Based on the significant correlation with nutrients and organic pollution variables, this study suggests that Saprobic Index (SI), Trophic Index (TI) and Swiss Diatom Index (DI-CH) are integrating the effects of enrichment of organic pollution. In another study, among the observed diatom indices, TI and DI-CH better reflect the changes in water quality than the SI (Kalyoncu et al., 2009). The diatom community is closely related to water quality and bio-invitational methods can be used in the river monitoring system in Turkey (Solak et al., 2012). Tortum River Basin has about 1900 km^2 area covering both Tortum and Uzundere towns and it is formed by Tortum Stream and its tributaries (Pırlak, 1993).

The aim of the present study was to evaluate the use of epilithic diatoms as indicators of water quality in the Tortum Stream and its tributaries.

MATERIALS AND METHODS

Study area

The Tortum Stream is located in the north part of the Eastern

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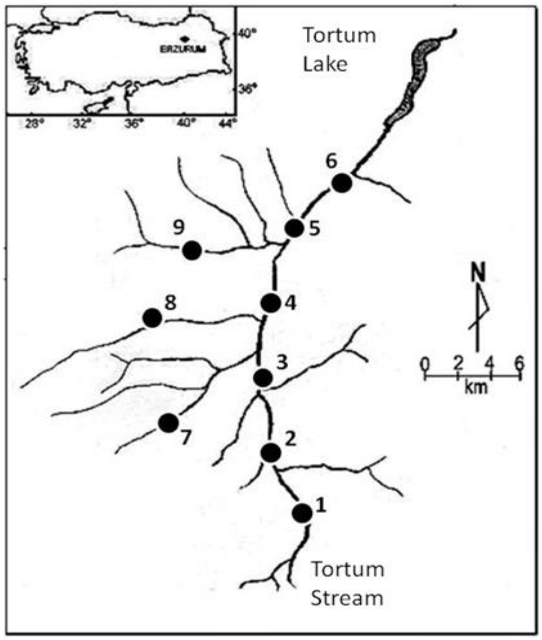

Figure 1. Location and the sampling stations of the Tortum Stream and its tributaries.

Anatolia, Turkey and its basin lies within the boundaries of Erzurum province. The stream form originates from town Tortum, forms the Tortum and the Tortum Waterfall, and then drains into the Coruh River (Figure 1). It has an average of 50 km length (Kıvrak and Gürbüz, 2010).

Diatom identification and counting

The diatom samples were collected from 9 stations monthly between June 2012 and May 2013. During the study period, the diatoms were sampled by scraping the 25 cm^2 upper surface of the epilithon, with a stiff toothbrush and collected in 250 ml sample bottle. The samples were fixed using Lugol's iodine. The composition and relative abundant of diatoms was estimated at 1000x magnification by binocular microscope and diatoms were identified after cleaning with a sulphuric and nitric acid mixture. The common taxonomic literatures were used (Krieger, 1932; Round, 1953; Cramer, 1991; Cox, 1996; Kelly, 1997; John et al., 2002). Three slides were prepared from each side and approximately 200 valves were enumerated in each slide to determine the relative abundance of each taxa (Kalyoncu et al., 2009).

Biodiversity indices

Five diversity indices (Shannon-Wiener, Simpson, Margalef, Menhinick, and McIntosh), two evenness indices and one dominant index were studied. MINITAB 15 (Cluster Observation) Software was used to interpret the relationship between the indices.

Shannon-Wiener diversity index (H')

This index is applied to biological systems which is derived from a mathematical formula by Shannon in 1948 (Türkmen and Kazancı, 2010):

$$H' = -\sum_{i=1}^{S} p_i \log_e p_i \,, \quad p_i: n_i/n$$

Where s is the total number of species and p_i is the number of individuals belonging to i species (n_i) / total number of individuals (n) (Hill, 1973; Krebs, 1998; Kwak and Peterson, 2007; James and Aderaje, 2010).

Simpson diversity index (D)

$$1 - D = \left[\sum ni(ni-1)\right] / N / (N-1)$$

Where ni is the number of individuals belonging to i species and N is the total number of species (Hill, 1973; Krebs, 1998; Kwak and Peterson, 2007; James and Aderaje, 2010).

Simpson dominance index (C)

$$C = \sum_{i=1}^{s} (p_i^{\,2}) \,,$$

Where s is the number of species and p_i is the relative abundance of species i (Hill, 1973; Krebs, 1998; Kwak and Peterson, 2007; James and Aderaje, 2010).

Margalef diversity index (Dmg)

$$D_{mg} = S - 1 / \mathrm{Log} N$$

Where S is the number of species and N signifies the number of individual in a sample (James and Aderaje, 2010).

Menhinick diversity index (D_{mn})

$$D_{mn} = S / \sqrt{N}$$

Where S is the number of species and N signifies the number of individual in a sample (Menhinick, 1964; James and Aderaje, 2010).

McIntosh diversity index (M_c)

$$M_c = \left[N - \sqrt{\left(\sum n_i^{\,2}\right)}\right] / \left[N - \sqrt{N}\right]$$

Where ni is the number of individuals belonging to i species and N is the number of species (Türkmen and Kazancı, 2010).

Pielou evenness index (J')

$$J' = H' / \log_e S$$

Where S is the number of species and H' is the Shannon-Wiener Diversity Index (Hill, 1973; Krebs, 1998; Kwak and Peterson, 2007; James and Aderaje, 2010).

Table 1. The list of diatoms in Tortum Stream.

Phyllum: Heterokontophyta	Order: Rhopalodiales
Classis: Bacillariophyceae	Family: Rhopalodiaceae
Order: Achantes	*Epithemia adnata* (Kützing) Brebisson
Family: Cocconeidaceae	*E. sorex* Kützing
Cocconeis placentula Ehrenberg	Order: Thalassşophyceae
Order: Bacillariales	Family: Catenulaceae
Family: Bacillariaceae	*Amphora ovalis* (Kützing) Kützing
Hantzshia amphioxys(Ehrenberg) Grunow	Classis: Coscinodiscophyceae
Nitzschia amphibian Grunow	Order: Aulacoseirales
Family: Surirellaceae	Family: Aulacoseiraceae
Suriella brebissonii Krammer & Lange-Bertalot	*Aulacoseria ambigua (Grunow)Simansen*
Order: Cymbellaceae	*A. granulata (Ehrenberg) Simansen*
Family: Cymbellaceae	Order: Thalassiosirales
Cymbella affinis Kützing	Family: Stephanodiscaceae
C. lensolata Cuspidata Pantocsek	Genus: Cyclotella
C. turgidula Grunow	*Cyclotella bodanica* Eulenstein ex Grunow
Encyonema minutum Hilse	*C. ocellata* Pantocsek
Family: Gomphonemataceae	Genus: Stephanodiscus
Didymosphenia geminata (Lyngbye) M. Schmidt	*Stephanodiscus rotula* (Kützing) Hendey
Gomphonema angustadum Kützing	*S. hantzschii* Grunow
G. capitatum Ehrenberg	Order: Melosirales
G.olivaceum (Hornemann) Brébisson	Family: Melosiraceae
G. parvalu (Kützing) Kützing	Genus: Melosira
Family: Rhoicospheniaceae	*Melosira varians* C.Agardh
Rhoicosphenia curuata (Kützing) Grunow	Classis: Fragilariophyceae
Order: Naviculales	Order: Fragilariales
Family: Naviculaceae	Family: Fragilariaceae
Caloneis bacillum (Grunow) Cleve	*Diatoma vulgaris* Bory de Sain-Vicent
Navicula cryptocephala Kützing	*Fragilaria arcus* (Ehrenberg) Cleve
Family: Pleurosigmataceae	*F.capucina* Desmazieres
Gyrosigma acuminatum (Kützing) Rabenhorst	*Meridion circulare* (Graville) C.Agardh
Family:Stauroneidaceae	*Ulnaria capidata* (Ehrenberg) P.Compere
Craticula cuspidata (Kützing) D.G.Mann	*U. ulna* (Nitzsch) P.Compere

McIntosh evenness index (M_cE)

$$M_cE = \left[N - \sqrt{\left(\sum n_i^2\right)}\right] / \left[N - \left(N/\sqrt{S}\right)\right]$$

Where ni is the i. türe ait birey sayısını, S is the number of species and Nis the number of individual (Türkmen and Kazancı, 2010).

RESULTS

In this study, a total of 3 classes, 10 orders, 15 families and 36 taxa, were identified belonging Bacillariophyceae (Table 1). While low species diversity was identified in summer, high species diversity was found between winter and spring (Table 2). During the study period, the highest total number of individuals was found in station 1 and the lowest total number in station 6. Total number of individuals was about 50% higher in the downstream sampling stations than in the upstream sampling stations. The number of species varied depending on station with an average of 24 species (Figure 2). The values of Shannon-Wiener Diversity Index ranged from 0.46 to 1.92. The lowest value was for station 2 and the highest for station 7. The values of Simpson Diversity Index were between 24.26 and 24.86. The lowest value was for station 2 and the highest value for station 7 (Figure 3).

In this study, *Cocconeis placentula* reached a significantly high abundance level in the all of the stations. In addition, both Shannon-Wiener Diversity and Simpson Diversity indexes were shown to be of eutrophication assessment in the stream ecosystem (Table 3). The values of Margalef Diversity Index ranged from 4.01 to 4.88. The lowest value was for station 2 and

Table 2. Monthly variation in species diversity ('+' indicates species, E not encountered).

Species	Months										
	Jun	Jul	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Aulacoseria ambigua (Grunow)Simansen	E	E	E	E	E	E	E	E	E	+	E
Caloneis bacillum (Grunow) Cleve	E	E	E	E	E	+	+	+	+	+	E
Cocconeis placentula Ehrenberg	+	+	+	+	+	+	+	+	+	+	+
Craticula cuspidata (Kützing) D.G.Mann	E	+	+	E	E	+	+	+	+	+	+
Cyclotella bodanica Eulenstein ex Grunow	E	+	E	E	E	E	+	+	E	E	E
C. ocellata Pantocsek	E	E	E	E	E	E	E	+	E	+	+
Cymbella affinis Kützing	E	+	+	+	E	E	+	+	E	+	+
C. lensolata Cuspidata Pantocsek	E	E	E	E	E	E	E	E	E	+	+
C. turgidula Grunow	E	E	E	E	+	E	+	+	+	+	+
Diatoma vulgaris Bory de Sain-Vicent	E	+	+	+	E	+	+	+	+	+	+
Didymosphenia geminata (Lyngbye) M. Schmidt	E	E	E	+	E	+	+	+	E	+	+
Encyonema minutum Hilse	E	E	E	E	E	E	E	+	E	E	E
Epithemia adnata (Kützing) Brebisson	E	E	E	E	E	E	+	E	E	+	+
E. sorex Kützing	E	E	E	E	E	E	E	E	E	E	E
Fragilaria arcus (Ehrenberg) Cleve	E	E	E	E	+	+	+	+	+	+	+
F.capucina Desmazieres	E	E	E	E	E	+	+	+		+	
Gomphonema angustadum Kützing	E	+	+	+	E	+	+	+	+	+	+
G. capitatum Ehrenberg	E	E	E	E	E	E	E	E	E	E	E
G. parvalu (Kützing) Kützing	E	E	E	E	E	E	E	E	E	E	E
G.olivaceum (Hornemann) Brébisson	E	E	E	E	E	E	+	E	E	E	E
Gyrosigma acuminatum (Kützing) Rabenhorst	E	E	E	E	E	E	+	E	E	E	+
Hantzshia amphioxys (Ehrenberg) Grunow	E	E	E	E	+	+	+	+	+	+	+
Melosira varians C.Agardh	E	+	E	E	E	E	+	+	+	+	+
Meridion circulare (Graville) C.Agardh	E		E	E	E	E		+			
Navicula cryptocephala Kützing	E	+	+	+	+	+	+	+	+	+	+
Nitzschia amphibian Grunow	E	+	+	+				+		+	+
Rhoicosphenia curuata (Kützing) Grunow	E	+	+	E	E	+	+	+	+	+	+
S. hantzschii Grunow	E	E	E	E	E	E	+	E	E	+	
Stephanodiscus rotula (Kützing) Hendey	E	E	E	E	E	E	+	E	E	+	
Suriella brebissonii Krammer & Lange-Bertalot	E	E	E	E	+	E	E	E	E	E	E
Ulnaria capidata (Ehrenberg) P.Compere	E	E	+	+	+	E	+	E	E	+	+
U. ulna (Nitzsch) P.Compere	E	E	+	+	+	E	+	+	+	+	+

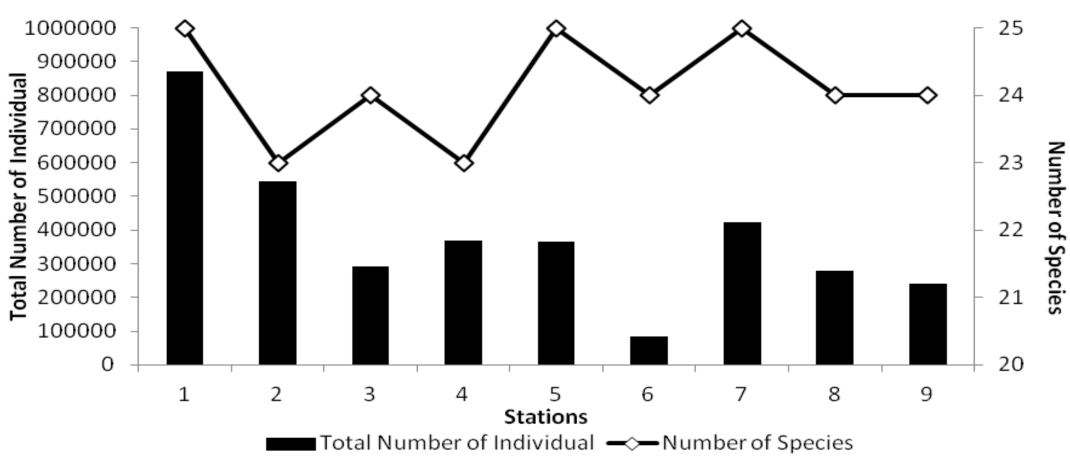

Figure 2. Total number of individual and species for each station.

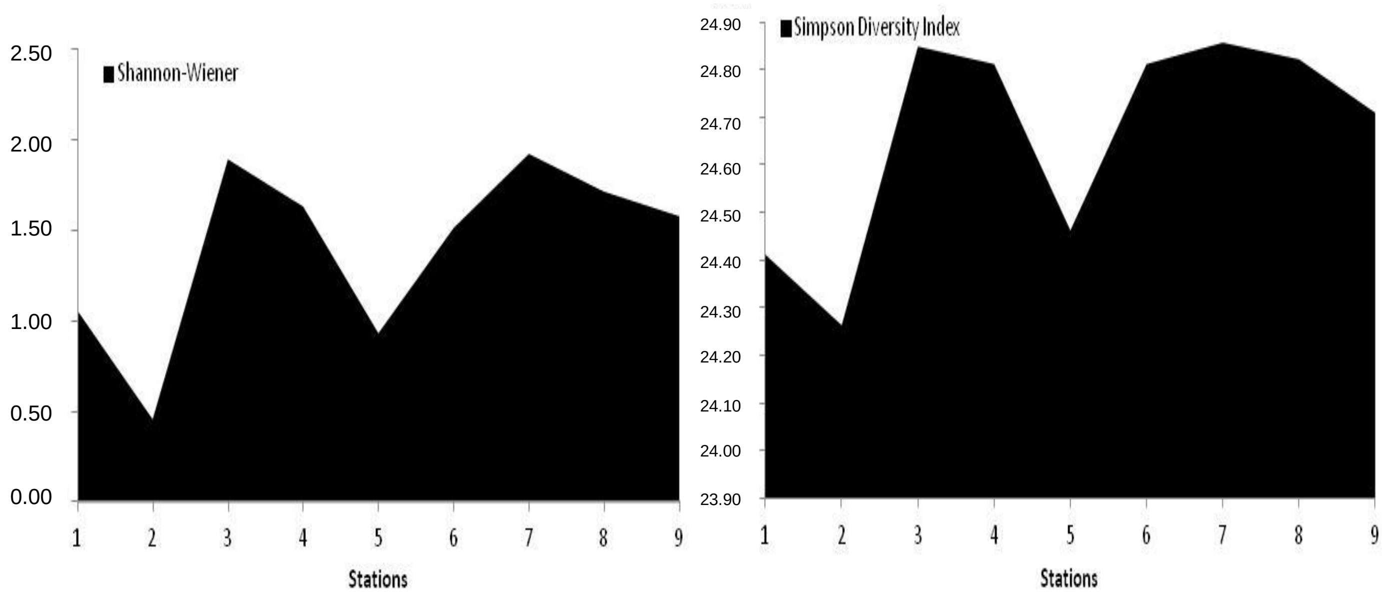

Figure 3. The variation of Shannon-Wiener Diversity and Simpson Diversity connect to station.

Table 3. Changes in dominant species to sample stations.

Station	Species	C
1	*Cocconeis placentula*	0.577
2	*Cocconeis placentula*	0.731
3	*Cocconeis placentula*	0.075
	Caloneis bacillum	0.044
4	*Cocconeis placentula*	0.121
	Navicula cryptocephala	0.047
5	*Cocconeis placentula*	0.527
6	*Cocconeis placentula*	0.136
	Navicula cryptocephala	0.015
	Cymbella affinis	0.025
7	*Cocconeis placentula*	0.029
	Diatoma vulgaris	0.034
	Ulnaria capidata	0.056
8	*Cocconeis placentula*	0.110
	Craticula cuspidata	0.533
9	*Cocconeis placentula*	0.266
	Ulnaria ulna	0.011

the highest value for station 6. These stations did not have a domestic land but they were under the stresses of dams conclusion and quarries. The values of Menhinick Diversity Index were between 0.03 and 0.08. The lowest value was for station 1 and 2 and the highest value for station 6. The values of McIntosh Diversity Index were between 288.295 and 736.85. The lowest value was calculated for station 6 and the highest value for station 2 (Figure 4).

Pielou Evenness Index was between 0.15 and 0.60. The lowest value was station 2 and the highest value was for stations 3 and 6. Both of them found similar value due to dam construction. The McIntosh Evenness Index was between 0.25 and 1.26. The lowest value was station for 2, 3, 4, 8 and 9 and the highest value was for station 5 and 7 (Figure 5). In this study, Shannon-Wiener and Simpson Diversity Indices, Margalef and Menhinick Diversity Indices were similar to each other (Figure 6). The number of species was similar for stations 1, 2, 5 and for stations 3, 8, 9, 7, 4 in the Tortum Stream and its tributaries. However, station 6 was not similar with the other stations (Figure 7).

DISCUSSION

The present study identified 36 species from Bacillariophyceae, whereas Kıvrak and Gürbüz (2010) found 113 taxa in the same habitat during the period of 2005-2006. Our results show that diatom species could be under the stress of dam construction. According to Simson et al. (2003), natural disasters for example, erosion are in charge of increase of sediment concentration in this circumstance which is a trigger of water quality change. In parallel with these changes are nagative effects diatom assemblages and species diversity.

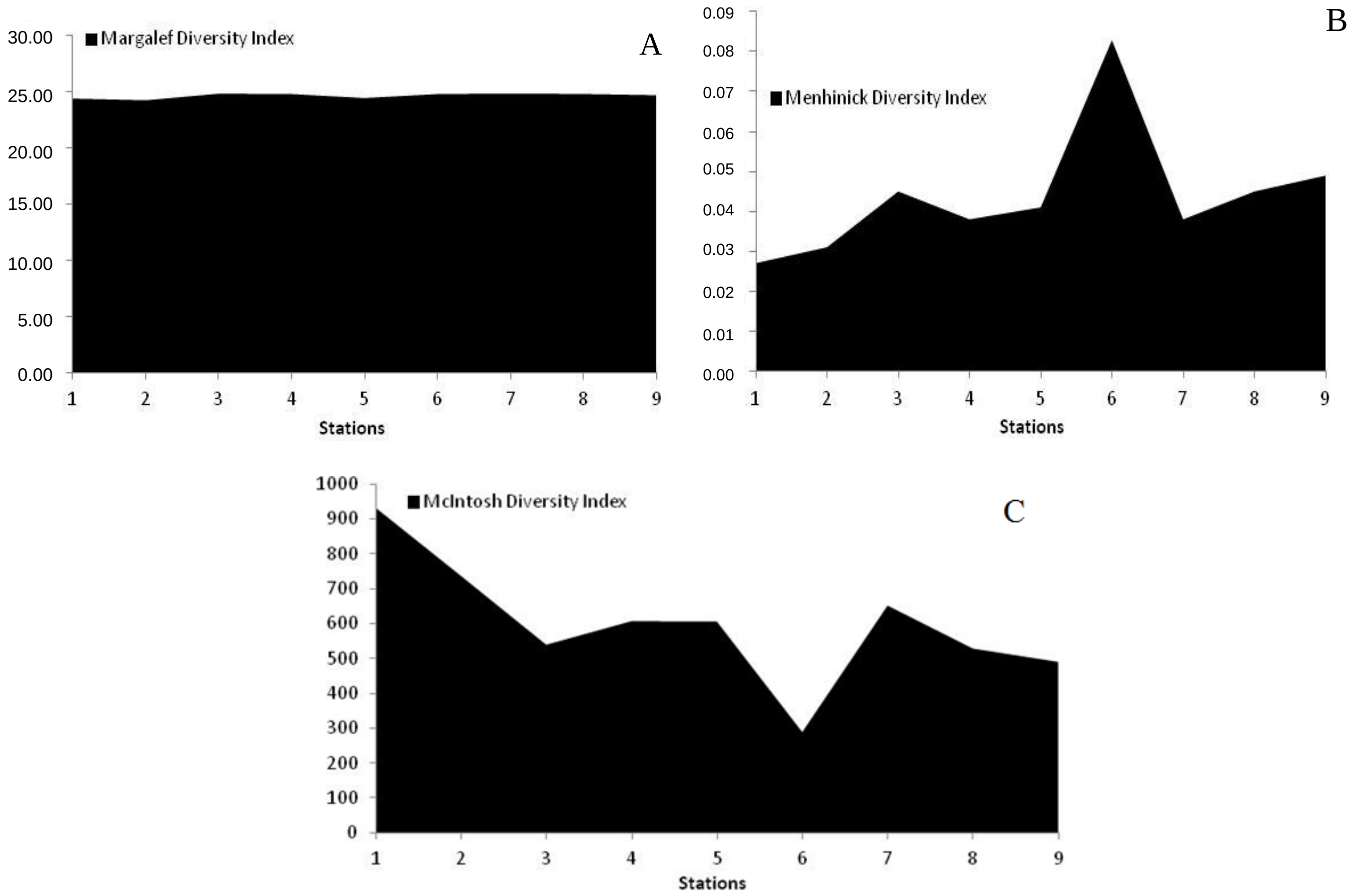

Figure 4. The variation of (A) Margalef Diversity, (B) Menhinick Diversity Index and (C) McIntosh Diversity Index.

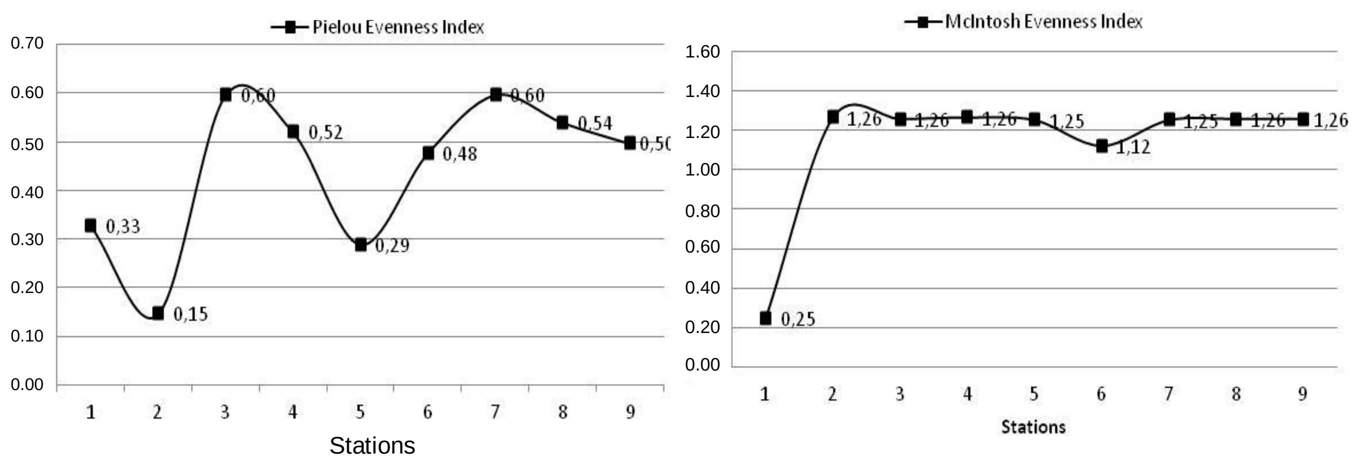

Figure 5. The variation of Pielou evenness index and the McIntosh connect to station.

In our study, *C. placentula* was the dominant taxa in all the stations. Kıvrak and Gürbüz (2010) identified *C. plasentula var. euglypta*. These taxa were adapted organic pollution (Soininen, 2002). *Caloneis bacillum* was found commonly in the station 3, *Navicula cryptocephala* was in the station 4, *Cymbella affinis* was in station 6, *Diatoma vulgaris* and *Ulnaria capidata* were in the station 7, *Craticula cuspidata* was in the station 8 and *Ulnaria*

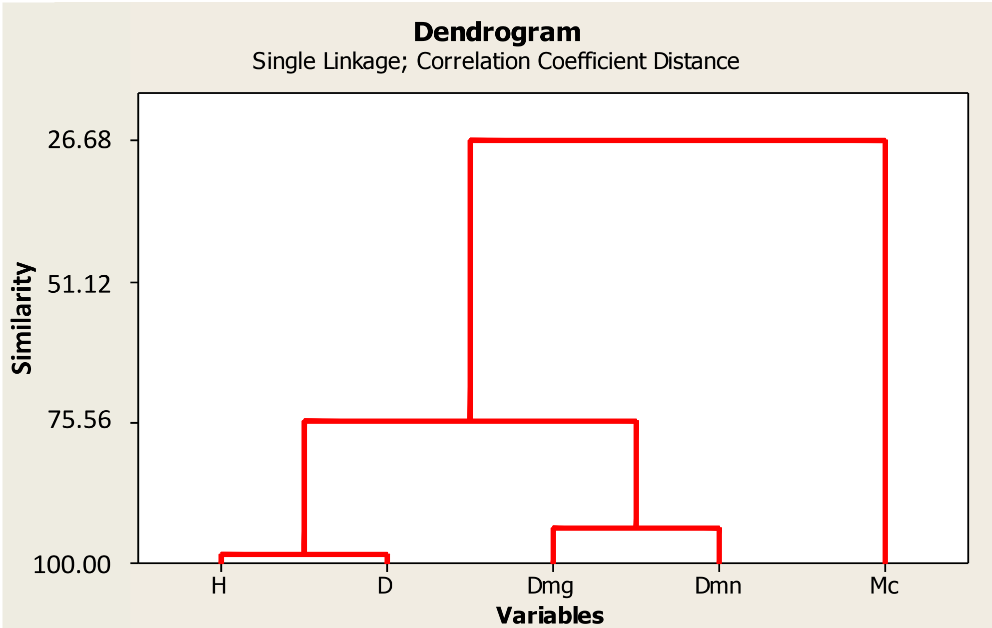

Figure 6. Similarity of different diversity indices.

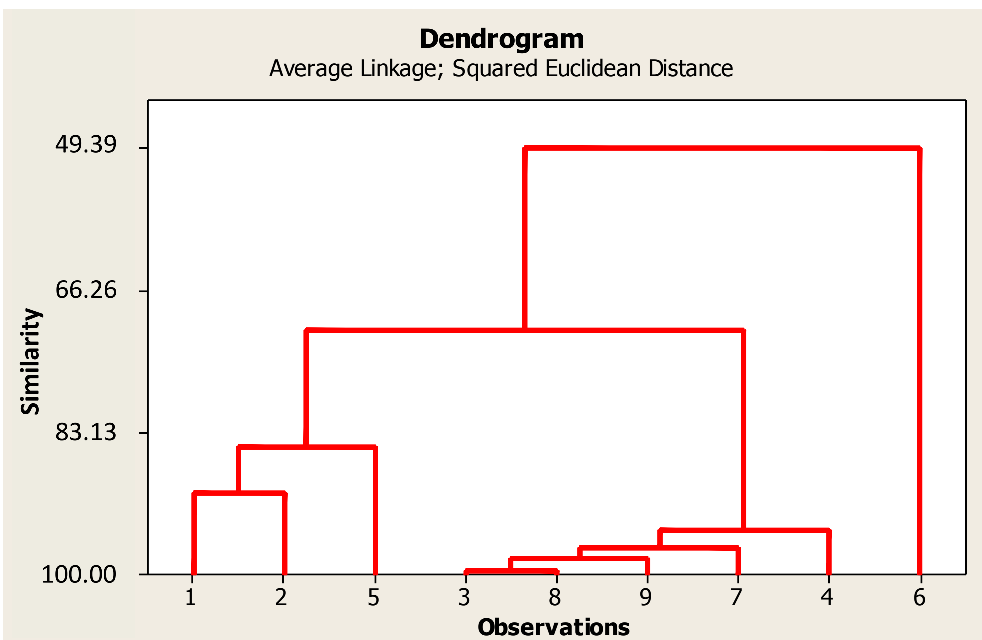

Figure 7. Similarity of different stations on the Tortum Stream and its tributaries.

ulna was in the station 9. This study showed that organic pollution-tolerant species were found in the stations which were located around the settlement and cultivation areas. On the other hand, dam construction and fast flow rate influence species diversity in the Tortum Stream.

In the present study, species diversity increased according to biodiversity indices in part of downstream and Tortum Stream's tributaries. The result of site 7 point out that around the station has been stressed both domestic and waste water pollutions. The structure of the ecosystem of rivers, streams on biodiversity, hydrological diversity and human activities are effective (Allan and Castillo, 2007). Pei and Liu (2011) suggested that dominant species were the upper more than middle part of Niyang River and they reported that useful indices can determine the ecological characteristics of lotic systems.

Conclusion

In conclusion, Tortum Stream and its tributaries were affected by domestic waste, agricultural waste, dam constructions and quarries. They created pressure on the ecosystem of the stream to reduce organic pollution-tolerant species. We suggest that precaution such as sewer system, demolition waste management (for example, dams and quarries) and control of illegal quarries should be taken in order to reduce detrimental effects of lotic ecosystem.

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