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Benthic algal diversity and water quality evaluation by biological approach of Turnasuyu Creek, NE Turkey

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ABSTRACT

Turnasuyu Valley is one of the most important green valleys in the north of Anatolia. Located in this valley, Turnasuyu Creek is the major stream of the region. The community structure of benthic algae in Turnasuyu Creek was studied over a 1-year period between February 2017 and January 2018 from three stations. The epilithic algal flora and the dominancy of identified species were determined. A total of 174 taxa were identified from epilithic habitats. In the community of epilithic algae, members of Bacillariophyta were dominant (88 taxa, 51%) and *Achnanthidium minutissimum* (Kützing) Czarnecki, *Cymbella affinis* Kützing and *Didymosphenia geminata* (Lyngbye) Mart. Schmidt, *Encyonema minutum* (Hilse) D.G. Mann, *Fragilaria capucina* Desmazières, *F. crotonensis* Kitton, *Hannaea arcus* (Ehrenberg) R.M.Patrick and *Ulnaria ulna* (Nitzsch) Compère have been the most frequent species found. In addition to diatoms, *Pseudanabaena* from Cyanobacteria, *Oedogonium* and *Ulothrix* from Chlorophyta and *Spirogyra* from Charophyta were the most frequent taxa in the algal flora. Assessment of physicochemical and biological data showed that the upstream region was oligosaprobic (clean) and the downstream region was oligo-β-mesosaprobic (clean to slightly pollute). Slight pollution in the downstream zone may be due to anthropogenic pressures. The general trophic status of Turnasuyu Creek is considered oligo-mesotrophic.

Keywords: Benthic algae; Bioindicators; Environmental factor; Stream; Water pollution; Water quality

1. Introduction

Having knowledge about the diversity of algae in freshwater is very important since most of the algal species are used as environmental indicators [1]. As rivers flow through a certain basin, their aquatic community structure differs depending on the ecological, geological, climatological and anthropogenic factors. The pollutants coming from point or nonpoint sources originating from agricultural, urban and/or industrial activities especially in the lower basins of rivers have adverse effects on the water quality and consequently, also change the structure of algae communities in the aquatic ecosystems. Spatial and temporal variation of algal communities is a good indicator of environmental changes as algae provide very good complementary and descriptive information about water quality by assessing the physicochemical parameters instantly. Benthic and planktonic algal species with bioindicator/biomonitor properties are, for this reason, used in water quality determination and monitoring programs [1–8]. The number of studies related in this regard has increased by the publication of the EU Water Framework Directive (WFD, 2000/60/EC). Under Turkish

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regulations, with their abundance, species diversity, and the presence of sensitive species, benthic algae are now classified as biological parameters in the monitoring of ecological status of river water bodies. They are especially used in monitoring studies of hydromorphological pressures (+), nutrients (+++), organic pollution (++) and acidification (++) [9,10]. Chlorophyll-a (chl-a) pigment as a biological indicator also provides information about aquatic productivity. Found in all algae groups, chl-a is a photosynthetic pigment and is a very good surrogate parameter for determination of algae biomass in the water.

Turnasuyu Creek is sourced from Çambaşı Plateau on the Mountains Canik with an elevation of 1,200–1,800 m, and merged into the Black Sea from the Turnasuyu area of Gülyalı town of Ordu. The precipitation area of the Turnasuyu Basin is 275 km^2, the total length of the stream is 56 km and the annual average flow rate is 7.6 m^3 s^{-1}. The upper basin of the stream has a cascade formation (andesite, basalt, tuff, sandstone, claystone) and the coastal part is a valley with an alluvial base. Turnasuyu Creek, which is mostly fed by runoff, is an irregularly regulated stream. The average annual precipitation in the area is 1,050–1,150 mm. Turnasuyu Creek has the potential to cause flood and coastal damage [11]. The site is located in the Euro-Siberian flora region. The area, with its temperate climate, is very convenient for plants because of the abundant rainfall. While it is expected to have a fairly lush vegetation, forest areas have been destroyed in order to cultivate hazelnut agriculture. However, the places where hazelnut farming cannot be done, the unsettled fields and the forested areas surrounded by the plateau spruce and pine forests in the upper basin have very rich plant diversity. Five species of fish (*Barbus tauricus, Capoeta banarescui, Squalius cephalus, Vimba vimba* and *Salmo labrax*) belonging to two families (Cyprinidae, Salmonidae) were reported to be living in Turnasuyu Creek [12]. Turnasuyu Stream is an ecologically important locality, especially as a spawning area for trout (*Salmo labrax*). In a study of the amount of heavy metal and macroelements in the *Typha latifolia* plant, distributed in wetlands down the river of Turnasuyu Creek, the order of the elements that accumulate in the plant has been reported as follow; N > P > K > Mg > Ca > Na > Fe > Mn > Zn > Pb > Cd > Cu [13]. As a result of the research, indicator algal species and some environmental parameters have shown that the downstream region of the river is under the pressure of anthropogenic factors. In another study of epiphytic algae and ecological characteristics in the downstream region of Turnasuyu Creek, 66 algal species have been identified. According to the indicator algal species and environmental parameters, it has been determined that the area has Class I and Class II water quality [14].

In order to efficiently utilize this water, it is necessary to determine the nutritional capacity of surface waters, their ecological condition and the kind of aquaculture they are suitable for. In addition, up-to-date information is needed to monitor the impact of global climate change on freshwater ecosystems. For this reason, it is very important to examine the environmental characteristics (physical and chemical factors) and algal diversity which constitute the first ring of the food chain and include indicator species. Surface water quality is greatly affected both by natural processes and by anthropogenic inputs. In limnological studies, integration of biological parameters together with physicochemical parameters presents better data for determining the water quality and ecological status of the aquatic ecosystem. Benthic algae, especially as one of the major biological elements in rivers, are a very good indicator. The species diversity, density and seasonal distribution of benthic algae play a very important role in determining the water quality of the environment.

In the present study, it was aimed to evaluate spatiotemporal epilithic algal diversity together with some physicochemical parameters in order to evaluate the water quality of Turnasuyu Creek and to determine the present ecological condition. The objectives of this first limnological study (algological – water quality) in the present area (Turnasuyu Valley) are as follows: (i) to evaluate the use of epilithic algae as biological indicator for the monitoring and protection of Turnasuyu Creek which constitutes one of Turkey's most important green valley, (ii) to determine some water quality parameters (iii) and to determine the ecological status of the stream according to the results of the dominant and common indicator algal species and water quality parameters.

2. Materials and methods

2.1. Description of study site

The sampling was carried out on three stations each month between February 2017 and January 2018 to determine the biological (epilithon, photosynthetic pigment) and ecological (some water quality parameters) properties of Turnasuyu Creek. For the purpose of fully characterizing the stream; the stations were identified from the upper basin toward the downstream area to determine the algal diversity of Turnasuyu Creek (Fig. 1).

Station 1: This sampling point was on the upper part of the stream and transportation with vehicle from this point forward is not possible. Located within the boundaries of Osmaniye Territory, this station is located at 40°54′27″ N and 37°59′06″ E coordinates with the altitude of 115 m. It is surrounded by forests and hazelnuts and consists of gray-brown podzolic soils. The basin of the river is stony-rocky. There is a rapid flow at this station. This station has a stone quarry on the western coast which leads the turbidity of water in rainy times.

Station 2: This sampling station was selected from the middle of the river. Located within the boundaries of Saraycık Territory, this station is located at 40°56′05′′ N and 37°58′43′′ E coordinates with a 40 m altitude. The basin of the river is stony-rocky. The slope is slight and the bed width is excessive. There is a rapid flow in rainy seasons. The station is surrounded by hazelnut gardens, consists of gray-brown podzolic soils and is located in the eastern part of the neighborhood Saraycık's residential area.

Station 3: This sampling station was selected from the lower part of the stream. Both sides of the stations are located in Turnasuyu's residential area. The station was 4 m above sea level and is located at 40°58′23″ N and 37°59′49″ E coordinates. Surrounded by settlements, there are hazelnut gardens on the slopes of hills and it is composed of alluvial lands. The slope is slight and the bed width is excessive. There is a rapid flow in rainy seasons.

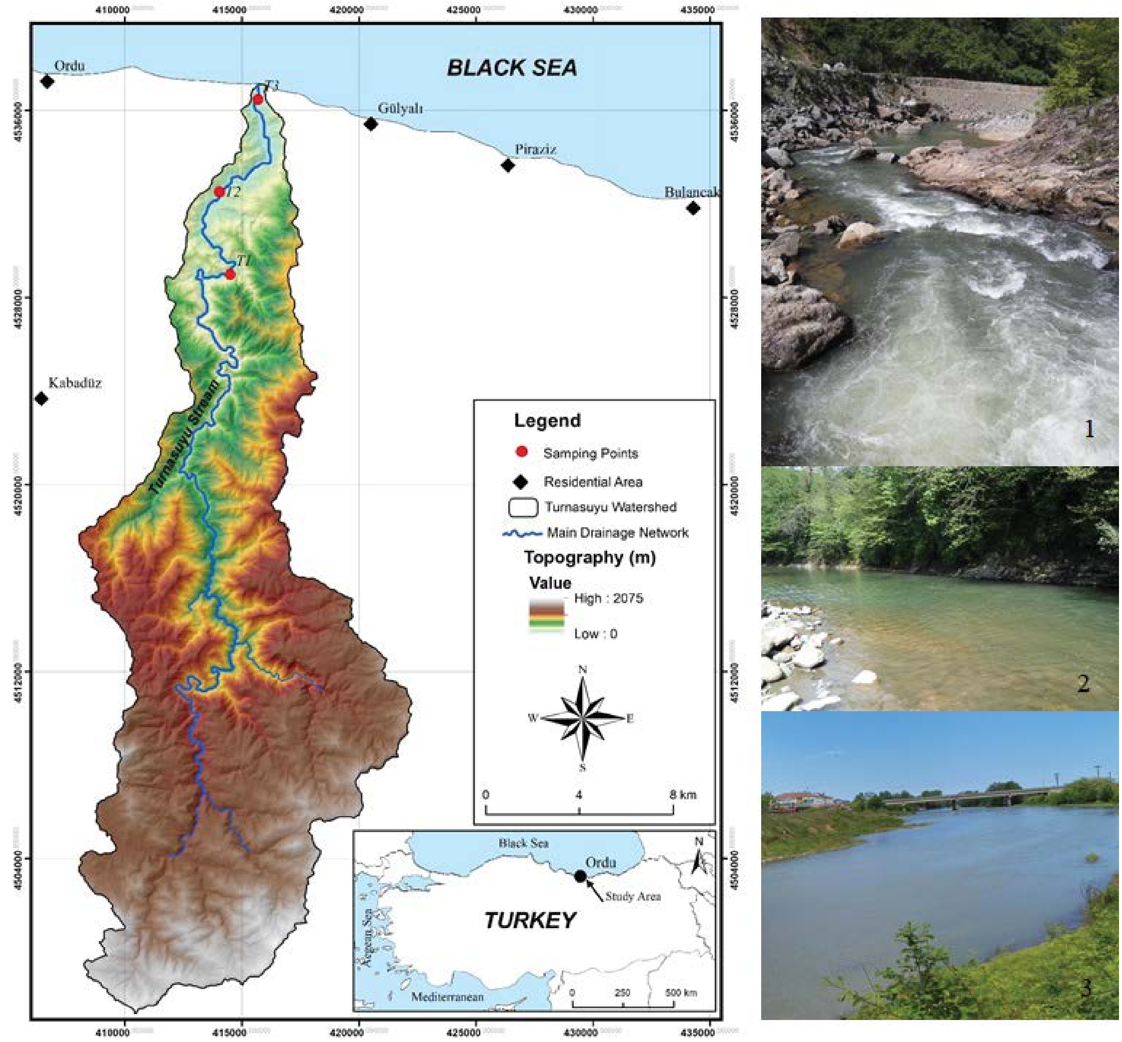

Fig. 1. Turnasuyu River Basin with sampling stations.

2.2. Sample collection and analytical procedures

2.2.1. Physical and chemical analysis

Water samples were collected from the basin in 1 L polyethylene bottles. The water temperature, pH, dissolved oxygen (DO), salinity, total dissolved solids (TDS) and electrical conductivity (EC) of each water sample were measured in situ by using the HACH multiparameter meter (Hach HQ40d multi-parameter pH/oximeter, Hach Company, USA) during the field studies, respectively. Nitrate nitrogen (NO_3–N), nitrite nitrogen (NO_2–N) and total phosphorus (TP) parameters were determined by using the DR 2800™ Spectrophotometer (Hach Company, USA) during the laboratory studies. Turbidity was measured by turbidimeters (Hach 2100Q™, Hach Company, USA). All water samples were analyzed within 24 h of collection.

2.2.2. Biological analysis – diagnosis of epilithic algae

Generally, days without precipitation were selected in the middle of each month to carry out samplings from the study site. Since algae attached to the rocks were to be examined, equal amounts of stone were taken at each sampling period and algae solution was obtained by scraping them in pure water or tap water. The collected material was fixed with a 4% formaldehyde solution. Identification of algae was done with the use of optical microscopes Leica DM500 (Wetzlar, Germany) and Nikon E200 (Melville, NY, USA). Diatom identifications were confirmed from permanent slides of cleaned diatom frustules, prepared using standard methods [15] and examined at 1,000×. Diatoms and soft algae were identified according to Cox [16], Krammer and Lange-Bertalot [17–20] and John et al. [21]. Species were identified according to international guides and the taxonomy follows the modern taxonomical system [22], which includes the recent taxonomic revision.

2.2.3. Photosynthetic pigment analysis (chl-a)

A 1-L subsurface water sample was taken from each location to determine the photosynthetic pigment content of the stream. The samples brought to the laboratory via the cold chain were filtered through glass fiber filter paper by means of a vacuum filtration system (1.2 μm pore size, Whatman™ GF/C). Filters placed in capped centrifuge tubes were stored at –20°C until analysis. The materials remaining in the filters were extracted with acetone (90% v/v) in the dark for 24 h at 4°C. Following the centrifugation, the supernatants were transferred to quartz baths and photometrically measured at the relevant wavelengths (SHIMADZU UV-1800, UV-VIS spectrophotometer, Japan). The concentration of chlorophyll-a was calculated using the standard method [23].

2.3. Determination of trophic status

Physicochemical and biological analysis results of Turnasuyu Creek were compared with Turkish Surface Water Quality Regulation [9] and water quality class was determined. The trophic structure of the stream was determined using the indicator algae [2,24–26].

2.4. Multivariate statistical analysis

All the data obtained were subjected to statistical analysis. One-way ANOVA and Tukey tests were used to determine whether there was a significant difference between the parameters' annual means, standard deviations, minimum and maximum values, and the averages of the parameters by the stations (SPSS 22 software packages). Multivariate analysis of the stream water quality data set was performed using principal component and cluster analysis techniques (BioDiversity professional software version 2.0).

3. Results

3.1. Environmental characteristics of water in Turnasuyu Creek

The results of some physicochemical and biological parameters of the stream, which were monthly performed in three stations between February 2017 and January 2018, are summarized in Table 1. The pH values at Turnasuyu Creek, which has an alkaline character, were measured between 7.0 and 9.0 during the study. The water temperature in Turnasuyu Creek varied by the seasons, the highest temperature being recorded during the summer (32.2°C, site 3, July) and the lowest value during the winter months (4.6°C, site 1, February). The highest pH value was measured at the beginning of the autumn (with 9.03, at site 3, in September) and the lowest pH value at the hottest time of the year (with 6.9, at site 1, in July). The mean DO concentration was recorded as 10.86 mg L^{-1} with the highest value of 13.62 mg L^{-1} recorded at site 2, in February and the minimum value of 9.02 mg L^{-1} recorded at site 2, in September. The monthly mean DO concentration was the highest (13.05 mg L^{-1}) in February and the lowest (9.48 mg L^{-1}) in July. The salinity was measured at a range of 0–1 ppt. TDS concentration was measured between 39.3 mg L^{-1} at site 1 in June and 112.6 mg L^{-1} at site 2 in September. The EC value was measured in the range of 50–180 μS cm^{-1} with the annual mean of 86.88 μS cm^{-1}. The highest EC value was 179.7 μS cm^{-1} recorded at site 3 in July and the minimum was 50.3 μS cm^{-1} recorded at site 1 in May. The monthly mean EC concentration was the highest (169.2 μS cm^{-1}) in September and the lowest (55.6 μS cm^{-1}) in March. The annual mean of turbidity was 9.32 NTU with the highest value of 19.10 NTU recorded at site 2 in February and the lowest value of 2.25 NTU recorded at site 1 in November. The maximum value of the total suspended solids (TSS) concentration was recorded at site 3 in August (32 mg L^{-1}), and the minimum value at site 1 and site 2 in December (5 mg L^{-1}). The concentration of NH_4–N, a nitrogenous nutrient compound, was measured at a range of 0.006 mg L^{-1} (at site 2 in November) and 0.079 mg L^{-1} (at site 2 in February). NO_2–N was measured at a very low mean value of 0.004 mg L^{-1} with the highest value of 0.007 mg L^{-1} at site 1 in March, and the lowest value of 0.001 mg L^{-1} at site 3 in both February and March. The NO_3–N concentration varied from 0.3 to 1.067 mg L^{-1}. The highest NO_3–N value was measured in December, and the lowest was measured in May. The annual average value of the TP concentration at Turnasuyu Creek, an important nutrient element, was 0.017 mg L^{-1}. The

Table 1
Water quality parameters at sampling locations in the Turnasuyu Creek

Parameters	Site 1	Site 2	Site 3	Minimum	Maximum	Mean (SD)
Temperature, °C	13.58	14.83	16.46	5	32	14.96 (7.18)
pH	8.69	8.62	8.51	7.0	9.0	8.61 (0.43)
Dissolved oxygen (DO), mg L^{-1}	10.75	10.95	10.90	9.0	14	10.86 (1.14)
Oxygen saturation (DO_{sat}), %	107.59	110.02	113.22	102	134	110.28 (7.32)
Salinity‰, ppt	0.03	0.05	0.05	0	0.1	0.04 (0.05)
Total dissolved solids (TDS), mg L^{-1}	61.0	68.0	69.0	39.0	113.0	66.0 (21)
Electrical conductivity (EC), μS cm^{-1}	76.63	89.38	94.61	50	180	86.88 (39.83)
Turbidity, NTU	9.24	8.65	10.07	2.0	19	9.32 (4.03)
Total suspended solids (TSS), mg L^{-1}	12.08	14.92	15.67	5.0	32	14.22 (6.41)
NH_4–N, mg L^{-1}	0.036	0.036	0.030	0.006	0.079	0.034 (0.02)
NO_2–N, mg L^{-1}	0.005	0.003	0.003	0.001	0.007	0.004 (0)
NO_3–N, mg L^{-1}	0.717	0.558	0.633	0.3	1.2	0.636 (0.3)
TP, mg L^{-1}	0.012	0.021	0.018	0.003	0.032	0.017 (0.01)
Chlorophyll-a (Chl-a), μg L^{-1}	0.489	0.490	0.486	0.31	0.6	0.488 (0.07)

highest value was 0.032 mg L^{-1} (at site 3, in March) and the lowest value was 0.003 mg L^{-1} (at site 1, in April).

3.2. Biological characteristics

The mean concentration of chl-a, which is one of the biological parameters of the stream and gives important information about the productivity in the water, was calculated as 0.49 μg L^{-1} in Turnasuyu Creek. The maximum value was recorded at site 1, 2 and 3 in February (0.596, 0.583 and 0.595 μg L^{-1}), and the minimum was again recorded at site 1 in July (0.31 μg L^{-1}). The seasonal variation of chl-a concentration is shown in Fig. 2.

A total of 174 taxa were detected in the epilithic algal communities in Turnasuyu Creek by monthly sampling from three stations (Table 2). Cyanobacteria (blue-green algae) were classified in a single class (Cyanophyceae, 25 taxa). Bacillariophyta (diatoms, siliceous algae) members were collected under three classes (Bacillariophyceae, 84 taxa; Coscinodiscophyceae, 2 taxa; Mediophyceae, 2 taxa). The most species diversity was formed by pennate diatoms in Bacillariophyceae. Euglenozoa was studied within a single class (Euglenophyceae, 6 taxa). Chlorophyta (green algae) is divided into three classes: Chlorophyceae (31 taxa), Trebouxiophyceae (4 taxa) and Ulvophyceae (2 taxa). The largest variety was recorded in the class of Chlorophyceae. Charophyta is divided into two classes: Conjugatophyceae (17 taxa) and Klebsormidiophyceae (1 taxon). Conjugatophyceae (conjugating green algae) are the main types of charophytes.

Diatoms (88 taxa, 51%) were the dominant algae group in Turnasuyu Creek epilithic flora. While the subdominant algae group was formed by green algae (37 taxa, 21%), the other algal groups were; blue-green algae (25 taxa, 14%), charophytes (18 taxa, 10%) and euglenoids (6 taxa, 4%). *Achnanthidium minutissimum, Cymbella affinis, Didymosphenia geminata, Encyonema minutum, Fragilaria capucina, F. crotonensis, Hannaea arcus* and *Ulnaria ulna* from diatoms; species of *Oedogonium* and *Ulothrix* genus from green algae; *Spirogyra* from Charophyta; *Pseudanabaena* species of blue-green algae were recorded as the densest species. *Oscillatoria limosa* from blue-green algae at site 2 and site 3 and *Oscillatoria tenuis* at site 3; only *Oedogonium* sp. from green algae were frequently recorded high at all stations. Having the most species diversity, diatoms species of *A. minutissimum*, *C. affinis*, *E. minutum*, *F. crotonensis*, *H. arcus* and *Reimeria sinuata* were recorded in all stations and *Melosira varians* and *U. ulna* were found at site 2 and site 3 to be frequently high. Diatoms were recorded at remarkable intensity and widely in all seasons (especially in winter, spring and autumn) among the common and abundant epilithic algae of Turnasuyu Creek. Diatoms such as *A. minutissimum*, *C. affinis*, *E. minutum*, *F. crotonensis* and *U. ulna* are abundant species in all seasons. In addition to the aforementioned high frequent diatoms (Table 2), *D. geminata*, an invasive species, was particularly intense at site 2 and site 3 in the spring. In the summer, diversity in green algae increased. *Scenedesmus* genus species were recorded in the middle of the summer. *Pseudanabaena catenata* from blue-green algae; *C. affinis*, *Navicula cryptocephala* and *Ulnaria ulna* species from the diatoms were among the abundant species in summer. In the autumn, filamentous species from blue-green and green algae (*Potamolinea aerugineo-caerulea*, *Oedogonium* spp., and *Spirogyra* spp.) were also abundantly recorded together with abundant diatoms (*A. minutissimum*, *C. affinis*, *F. crotonensis*, *U. ulna*). Table 3 presents some ecological characteristics of the common and abundant species in Turnasuyu Creek. The common and abundant species in Turnasuyu Creek during the study period were within the five different functional groups as *P*, T_C, T_D, T_B and *J*.

The result of the principle component analysis (PCA) base on the correlation matrix of physicochemical and biological components is expressed in Table 4. The sampling sites were the dependent variables, while the measured parameters constituted the independent variables. The eigenvalue data set is divided into three groups according to the results of the PCA and shows 100% of the variance in the data set. The first component (PC1) generated over 99% of the total variance in the data set and contained all the environmental parameters. This component showed strong positive loading especially for major ions such as DO (sat %), TDS and EC. The highest similarity (97.98%) in terms of environmental conditions is between site 2 and site 3, as seen in the dendrogram obtained by comparing the Bray–Curtis similarity index to the results of the analysis of environmental parameters (Fig. 3). The similarity between site 1, at the top of the stream, and site 2,

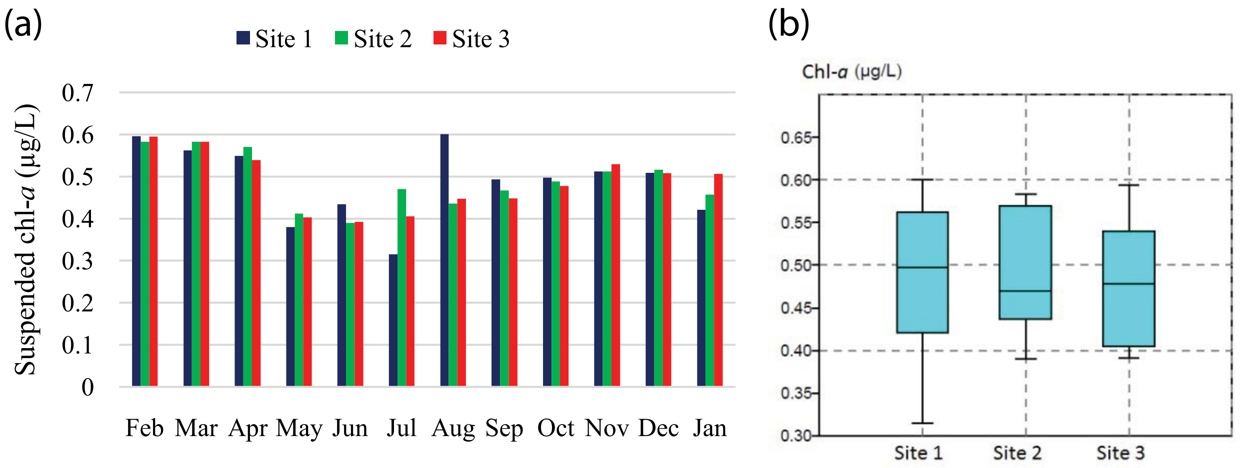

Fig. 2. Seasonal variation of suspended chl-a concentration in Turnasuyu Creek (a) monthly change and (b) boxplot graph of stations.

Table 2
List and frequency distribution of epilithic taxa found during the study period

Taxon	Author	Frequency (%) S1	S2	S3
CYANOBACTERIA, Cyanophyceae, Blue-green algae		56%	72%	92%
Anabaena sp.		*X*	*X*	*X*
Calothrix parietina	Thuret ex Bornet and Flahault	*X*	*X*	*X*
Chlorogloea rivularis	(Hansgirg) Komárek and Anagnostidis	*X*	*X*	*X*
Chroococcus turgidus	(Kützing) Nägeli	*R*	*R*	*R*
Kamptonema formosum (Basionym: *Oscillatoria formosa*)	(Bory ex Gomont) Strunecký, Komárek and J. Smarda	–	*X*	*X*
Komvophoron minutum	(Skuja) Anagnostidis and Komárek	–	–	*X*
Komvophoron schmidlei	(Jaag) Anagnostidis and Komárek	*X*	*X*	–
Leptolyngbya polysiphoniae	(Frémy) Anagnostidis	–	–	*X*
Lyngbya martensiana	Meneghini ex Gomont	–	*X*	–
Merismopedia tenuissima	Lemmermann	*X*	*R*	*R*
Microcoleus autumnalis	(Gomont) Strunecky, Komárek and J.R. Johansen	–	–	*X*
Oscillatoria anguina	Bory ex Gomont	–	*X*	*R*
Oscillatoria limosa	C. Agardh ex Gomont	*C*	*H*	*H*
Oscillatoria tenuis	C. Agardh ex Gomont	*R*	*F*	*H*
Phormidium sp.		–	*X*	*X*
Planktolyngbya limnetica	(Lemmermann) Komárková-Legnerová and Cronberg	*X*	*R*	*X*
Planktothrix agardhii	(Gomont) Anagnostidis and Komárek	*X*	*R*	*X*
Planktothrix rubescens	(De Candolle ex Gomont) Anagnostidis and Komárek	–	–	*X*
Pleurocapsa minor	Hansgirg	*X*	*X*	*X*
Pleurocapsa sp.		–	–	*X*
Potamolinea aerugineo-caerulea (Syn: *Lyngbya aerugineo-caerulea*)	(Gomont) M.D. Martins and L.H.Z. Branco	*R*	*R*	*R*
Pseudanabaena catenata	Lauterborn	*C*	*X*	*C*
Pseudanabaena limnetica (Basionym: *Oscillatoria limnetica*)	(Lemmermann) Komárek	*C*	*F*	*F*
Spirulina major	Kützing ex Gomont	–	–	*X*
Synechococcus elongatus	(Nägeli) Nägeli	–	–	*X*
BACILLARIOPHYTA, Bacillariophyceae, Diatoms		82%	75%	80%
Achnanthidium minutissimum	(Kützing) Czarnecki	*H*	*H*	*H*
Achnanthidium rivulare	Potapova and Ponader	*X*	*X*	–
Amphora ovalis	(Kützing) Kützing	*X*	*X*	*X*
Brachysira microcephala (Basionym: *Navicula microcephala*)	(Grunow) Compère	*C*	*X*	*R*
Centronella reicheltii	Max Voigt	*X*	–	–
Cocconeis placentula var. *lineata*	(Ehrenberg) Van Heurck	*F*	*F*	*F*
Cymbella affinis	Kützing	*H*	*H*	*H*
Cymbella cistula (Basionym: *Bacillaria cistula*)	(Ehrenberg) O. Kirchner	*R*	*R*	*R*
Cymbella lanceolata	(C. Agardh) C. Agardh	*R*	*R*	*F*
Cymbella tumida	(Brébisson) Van Heurck	*X*	*X*	*R*
Cymbella tumidula	Grunow	*R*	*C*	*C*
Cymbella turgidula	Grunow	*X*	*X*	*X*
Diatoma ehrenbergii	Kützing	*X*	–	*X*
Diatoma moniliformis	(Kützing) D.M. Williams	*X*	–	–
Diatoma vulgaris	Bory	*R*	*R*	*C*
Didymosphenia geminata	(Lyngbye) Mart. Schmidt	*C*	*F*	*F*

Encyonema caespitosum	Kützing	–	–	*X*
Encyonema leibleinii	(C. Agardh) W.J. Silva, R. Jahn, T.A. Veiga Ludwig and M. Menezes	*X*	*X*	*X*
Encyonema minutum (Basionym: *Cymbella minuta*)	(Hilse) D.G. Mann	*H*	*H*	*H*
Encyonema perpusillum	(Cleve-Euler) D.G. Mann	*X*	*X*	*X*
Encyonema silesiacum	(Bleisch) D.G. Mann	*X*	*X*	*X*
Encyonopsis microcephala	(Grunow) Krammer	*X*	–	–
Eunotia bilunaris (Basionym: *Synedra bilunaris*)	(Ehrenberg) Schaarschmidt	–	–	*X*
Eunotia exigua f. *linearis*	Krasske	*X*	*X*	*X*
Eunotia monodon	Ehrenberg	–	*X*	*X*
Fallacia litoricola	(Hustedt) D.G. Mann	*X*	*X*	*X*
Fistulifera saprophila (Basionym: *Navicula saprophila*)	(Lange-Bertalot and Bonik) Lange-Bertalot	–	*X*	–
Fragilaria acus (Basionym: *Synedra acus*)	(Kützing) Lange-Bertalot	*X*	*X*	*X*
Fragilaria capucina	Desmazières	*C*	*F*	*F*
Fragilaria crotonensis	Kitton	*H*	*H*	*H*
Fragilaria mesolepta	Rabenhorst	–	*X*	*X*
Fragilaria vaucheria	(Kützing) J.B. Petersen	*R*	*R*	*R*
Gomphoneis clevei (Basionym: *Gomphonema clevei*)	(Fricke) Gil	*X*	–	–
Gomphonema acuminatum	Ehrenberg	*X*	*X*	–
Gomphonema gracile	Ehrenberg	*X*	*X*	*X*
Gomphonema minutum	(C. Agardh) C. Agardh	*C*	*F*	*F*
Gomphonema olivaceum (Syn: *G. clavatum*)	(Hornemann) Brébisson	*R*	*C*	*R*
Gomphonema parvulum	(Kützing) Kützing	*R*	*R*	*X*
Gomphonema truncatum	Ehrenberg	*C*	*R*	*X*
Gyrosigma acuminatum	(Kützing) Rabenhorst	*X*	–	*X*
Gyrosigma scalproides	(Rabenhorst) Cleve	*R*	*X*	–
Hannaea arcus	(Ehrenberg) R.M.Patrick	*H*	*H*	*H*
Hannaea arcus var. *arcus*	(Ehrenberg) Patrick	*X*	*R*	*R*
Hannaea linearis (Syn: *H. arcus* var. *linearis*)	(Holmboe) Álvarez-Blanco and S.Blanco	*X*	–	–
Hantzschia amphioxys	(Ehrenberg) Grunow	*X*	*X*	*X*
Hippodonta hungarica (Basionym: *Navicula hungarica*)	(Grunow) Lange-Bertalot, Metzeltin and Witkowski	*R*	*R*	*R*
Iconella tenera (Syn: *Surirella tenera*)	(W.Gregory) Ruck and Nakov	*X*	–	–
Mayamaea atomus	(Kützing) Lange-Bertalot	–	–	*X*
Meridion circulare	(Greville) C. Agardh	*X*	–	*X*
Navicula cryptocephala	Kützing	*F*	*F*	*F*
Navicula cryptotenella	Lange-Bertalot	*X*	*X*	*X*
Navicula lanceolata	Ehrenberg	–	–	*X*
Navicula menisculus	Schumann	*R*	*R*	*X*
Navicula reinhardtii	(Grunow) Grunow	–	*X*	–
Navicula rhynchocephala	Kützing	*C*	*C*	*C*
Navicula salinicola	Hustedt	*X*	–	–
Navicula veneta	Kützing	*C*	*F*	*F*
Navicula sp.		–	–	*X*
Nitzschia acicularis	(Kützing) W. Smith	*X*	*X*	*X*
Nitzschia amphibia	Grunow	–	*X*	*X*
Nitzschia bacillum	Hustedt	*X*	*X*	–
Nitzschia clausii	Hantzsch	*X*	*R*	*R*
Nitzschia dissipata	(Kützing) Rabenhorst	*R*	*R*	*C*
Nitzschia intermedia	Hantzsch	–	*X*	*X*
Nitzschia microcephala	Grunow	*X*	*X*	*X*

(Table 2 Continued)

Taxon	Author	Frequency (%)		
		S1	S2	S3
Nitzschia sociabilis	Hustedt	*X*	*X*	–
Odontidium mesodon (Basionym: *Fragilaria mesodon*; Syn: *Diatoma mesodon*)	(Kützing) Kützing	*R*	*X*	*R*
Pinnularia mesolepta	(Ehrenberg) W. Smith	*X*	–	–
Pinnularia microstauron	(Ehrenberg) Cleve	*X*	*X*	*X*
Pinnularia viridis	(Nitzsch) Ehrenberg	*X*	–	*X*
Reimeria sinuata	(W. Gregory) Kociolek and Stoermer	*H*	*H*	*H*
Rhoicosphenia abbreviata	(C. Agardh) Lange-Bertalot	*C*	*F*	*F*
Rhopalodia sp.		–	*X*	–
Stauroneis anceps	Ehrenberg	*X*	*X*	*X*
Staurosira construens	Ehrenberg	*R*	*R*	*R*
Staurosira leptostauron	(Ehrenberg) Kulikovskiy and Genkal	–	–	*X*
Staurosirella martyi (Basionym: *Martyana martyi*)	(Héribaud-Joseph) E.A. Morales and K.M. Manoylov	*X*	*X*	–
Surirella angusta	Kützing	*R*	*R*	*R*
Surirella brebissonii	Krammer and Lange-Bertalot	–	–	*X*
Surirella minuta	Brébisson ex Kützing	*X*	*X*	*R*
Tabellaria fenestrata	(Lyngbye) Kützing	*X*	–	–
Tetracyclus rupestris	(Kützing) Grunow	*R*	*X*	*X*
Ulnaria acus (Syn: *U. ulna* var. *acus*)	(Kützing) Aboal	X	X	X
Ulnaria ulna (Syn: *Synedra ulna*)	(Nitzsch) Compère	*F*	*H*	*H*
BACILLARIOPHYTA, Coscinodiscophyceae, Diatoms				
Ellerbeckia arenaria	(D. Moore ex Ralfs)	–	–	*X*
Melosira varians	C. Agardh	*F*	*H*	*H*
BACILLARIOPHYTA, Mediophyceae, Diatoms				
Cyclotella meneghiniana	Kützing	*R*	*R*	*C*
Pantocsekiella ocellata (Basionym: *Cyclotella ocellata*)	(Pantocsek) K.T. Kiss and E. Ács	–	–	*X*
EUGLENOZOA, Euglenophyceae, Euglenoids		50%	33%	83%
Euglena agilis	H.J. Carter	*R*	*R*	*C*
Euglena gracilis	G.A. Klebs	–	–	*X*
Lepocinclis ovum	(Ehrenberg) Lemmermann	*X*	–	*R*
Phacus hamelii	Allorge and Lefèvre	–	–	*X*
Trachelomonas oblonga	Lemmermann	*X*	*R*	–
Trachelomonas volvocina	(Ehrenberg) Ehrenberg	–	–	*X*
CHLOROPHYTA, Chlorophyceae, Green algae		68%	81%	89%
Ankistrodesmus arcuatus (Syn: *Monoraphidium arcuatum*)	Korshikov	*X*	–	*X*
Ankistrodesmus falcatus	(Corda) Ralfs	–	–	*X*
Ankistrodesmus spiralis	(W.B. Turner) Lemmermann	–	–	*X*
Chlamydomonas sp.1 (ovoid)		*X*	*X*	*R*
Chlamydomonas sp.2 (orbicular)		*X*	*R*	*R*
Coelastrum microporum	Nägeli	*X*	*X*	*X*
Desmodesmus abundans (Syn: *Scenedesmus abundans*)	(Kirchner) E. Hegewald	*X*	*R*	*R*
Desmodesmus communis (Basionym: *S. communis*)	(E. Hegewald) E. Hegewald	*R*	*R*	*F*
Desmodesmus denticulatus (Basionym: *S. denticulatus*)	(Lagerheim) S.S. An, T. Friedl, E. Hegewald	–	*X*	–
Microspora sp.		*X*	*X*	*X*
Microspora stagnorum	(Kützing) Lagerheim	*X*	*X*	*X*
Monoraphidium caribeum	Hindák	–	*X*	*X*

Monoraphidium contortum	(Thuret) Komárková-Legnerová	–	*X*	*X*
Monoraphidium griffithii	(Berkeley) Komárková-Legnerová	*R*	*R*	*X*
Monoraphidium irregulare	(G.M. Smith) Komárková-Legnerová	*R*	*R*	*X*
Monoraphidium minutum (Syn: *Selenastrum minutum*)	(Nägeli) Komárková-Legnerová	*C*	*R*	*C*
Monoraphidium tortile	(West, G.S. West) Komárková-Legnerová	–	*X*	–
Monoraphidium sp.		*X*	*R*	*C*
Oedogonium sp.1		*X*	–	*X*
Oedogonium sp.2		*H*	*H*	*H*
Pandorina morum	(O.F. Müller) Bory	–	*X*	–
Pediastrum boryanum var. *cornutum*	(Raciborski) Sulek	–	–	*X*
Scenedesmus ecornis	(Ehrenberg) Chodat	*X*	*X*	*C*
Scenedesmus ellipticus	Corda	*R*	*C*	*C*
Stauridium tetras	(Ehrenberg) E. Hegewald	*X*	*X*	*X*
Stigeoclonium tenue	(C. Agardh) Kützing	*R*	*R*	*R*
Tetradesmus dimorphus (Syn: *Scenedesmus dimorphus*)	(Turpin) M.J. Wynne	*X*	*R*	*R*
Tetradesmus lagerheimii (Syn: *S. acuminatus*)	M.J. Wynne and Guiry	*R*	*C*	*C*
Tetraëdron caudatum	(Corda) Hansgirg	–	–	*X*
Tetraëdron minimum	(A. Braun) Hansgirg	*X*	*X*	*R*
Tetrastrum glabrum	(Y.V. Roll) Ahlstrom and Tiffany	–	*X*	*X*
CHLOROPHYTA, Trebouxiophyceae, Green algae				
Actinastrum hantzschii	Lagerheim	*X*	*R*	*X*
Actinastrum hantzschii var. *subtile*	J. Woloszynska	–	*X*	–
Chlorella sp.		*X*	–	*X*
Closteriopsis acicularis	(Chodat) J.H. Belcher and Swale	–	*X*	*X*
CHLOROPHYTA, Ulvophyceae, Green algae				
Ulothrix tenerrima	(Kützing) Kützing	*R*	*C*	*X*
Ulothrix zonata	(F. Weber and Mohr) Kützing	*R*	*C*	*F*
CHAROPHYTA, Conjugatophyceae, Charophytes		56%	78%	78%
Closterium acerosum	Ehrenberg ex Ralfs	–	–	*X*
Closterium leibleinii	Kützing ex Ralfs	–	*X*	–
Closterium littorale	F. Gaynii	*X*	*X*	*R*
Cosmarium binum	Nordstedt	*X*	*X*	*X*
Cosmarium botrytis	Meneghini ex Ralfs	*X*	*X*	*X*
Cosmarium granatum	Brébisson ex Ralfs	–	*X*	–
Cosmarium impressulum	Elfving	–	–	*X*
Cosmarium pyramidatum	Brébisson ex Ralfs	–	*X*	–
Cosmarium regnellii	Wille	*X*	*X*	*X*
Cosmarium subcostatum	Nordstedt	*X*	*X*	*X*
Cosmarium subcrenatum	Hantzsch	*R*	*C*	*C*
Mougeotia robusta	(De Bary) Wittrock	–	*X*	*X*
Mougeotia scalaris	Hassall	–	–	*X*
Planotaenium interruptum (Basionym: *Penium interruptum*; Syn: *Netrium interruptum*)	(Brébisson ex Ralfs) Petlovany and Palamar-Mordvintseva	*X*	*X*	–
Spirogyra fluviatilis	Hilse	*R*	*X*	*C*
Spirogyra majuscula	Kützing	*X*	*X*	*R*
Spirogyra varians	(Hassall) Kützing	*X*	*X*	*X*
CHAROPHYTA, Klebsormidiophyceae, Charophytes				
Klebsormidium rivulare	(Kützing) M.O. Morison and Sheath	–	–	*X*

Frequency (%) = (Number of sampling units in which the species occurred × 100)/total number of sampling units studied.
Legend of occurrence frequency: Sporadically (*X* = 1%–20%), rarely (*R* = 21%–40%), commonly (*C* = 41%–60%), frequently (*F* = 61%–80%) and high frequently (*H* = 81%–100%).

Table 3
Ecology and geographical distribution of common and dominant algae

Species	Ecological characters				
	Habitat	Sap	Halobity	pH	Geo
Achnanthidium minutissimum	B	o–β	i	ind	K
Cymbella affinis	B	β–o	i	alf	K
Didymosphenia geminata	B	o–α	i	ind	K
Encyonema minutum	B	x–o	i	ind	K
Fragilaria capucina	B–P	o–β	i	alf	K
Fragilaria crotonensis	B–P	α–β	hl	alf	K
Hannaea arcus	B	x	i	alf	A–A
Ulnaria ulna	B	o–α	i	alf	K
Pseudanabaena limnetica	–	β–o	–	–	–
Oedogonium sp.	B	o–α	i	–	–
Scenedesmus spp.	B–P	–	–	–	K
Ulothrix zonata	B–P	o–α	i	–	–
Spirogyra varians	B–P	β–α	oh	–	K

Habitat: B = benthic, B–P = benthic-planktonic; Self-purification zone (Sap): x = xenosaprobity, o = oligosaprobity, o–β = oligo-β-mesosaprobity, β = β-mesosaprobity, β-α = β-α-mesosaprobity, α = α-mesosaprobity; Halobity: oh = oligohalob, i = oligohalob-indifferent, hl = oligohalob-halophil, pH: ind = pH indifferent and/or neutrophil, alf = alkaliphil, alb = alkalibiont, acf = acidophil; Geographic distribution (Geo): K = cosmopolite, A-A = arcto-alpine, - = no data.

Table 4
Result of the PCA

Parameters	PC1	PC2	PC3
Temperature	25.906	–1.823	0.876
pH	14.907	0.119	–0.067
DO	18.822	–0.128	–0.063
DO_{sat}	191.006	–3.511	1.669
Sali	0.0751	–0.0161	–0.003
TDS	114.318	–6.111	–0.267
EC	150.474	–12.894	1.709
Turb	16.143	–0.241	0.972
TSS	24.637	–2.664	0.120
NH_4–N	0.059	0.003	–0.004
NO_2–N	0.006	0.002	0.0002
NO_3–N	1.102	0.091	0.067
TP	0.029	–0.006	–0.003
Chl-a	0.846	0.002	–0.003
Eigenvalue	2.9966	0.0042	0.0002
Cumulative %	99.856	99.995	100

in the middle of the stream, is 95.65%. The least similarities (93.86%) were recorded between site 1 and site 3, the top and bottom sampling points of the stream, respectively.

4. Discussion

Surface water quality in Turkey is divided into four classes: Class I "very good" water, Class II "good" water status, Class III "medium" water status, and Class IV "bad" water availability [9]. The annual mean values of all environmental parameters in the study showed that the water quality of Turnasuyu Creek was Class I (Table 1). The results are also within Class I according to WFD (Directive 2000/60/EC) and the Environmental Protection Agency [27] criteria. In the present study conducted in the Turnasuyu Basin, environmental factors showed both temporal and spatial fluctuations. Typical seasonal changes have been recorded in the research area which is under the influence of temperate ocean climate. In the stream where the water temperature is optimal (mean 15°C, ≤25°C), the pH of the water is alkaline. Concentration of DO in water is very high (>8 mg L^{-1}, >90%). In particular, the upstream region has ecological characteristics suitable for salmonids. TDS values in streams can reach a maximum of 1,500 mg L^{-1}. In our study, the maximum TDS was 113 mg L^{-1} (TDS < 300 mg L^{-1}) and the mean concentration was 66 mg L^{-1}. Closely related to TDS, the EC value in rivers varies in the range of 50–1,500 µS cm^{-1}. According to the EC value measured within the range of 50–180 µS cm^{-1} in our study, Turnasuyu Creek is in the saltless salty class; (0–0.1‰, with the mean value of 0.04‰) has freshwater characteristics (0–5) according to the salinity value [28]. The 50 NTU turbidity value in the rivers is a sign of turbidity. In our study area, turbidity is very low with the measured values at 2–19 NTU. The TSS value also changed from 5 to 32 mg L^{-1} (with the mean value of 14.22 mg L^{-1}). With respect to nitrogen compounds (N–NH_4 < 0.2, N–NO_2 < 0.01, N–NO_3 < 5; mg L^{-1}), there is no pollution in the stream, and it has Class I water quality. All stations have Class I water quality characteristics based on the total phosphorus average value (TP < 0.03 mg L^{-1}), which is the most important nutrient in algal production. The only one TP value of 0.032 mg L^{-1} measured as the maximum from site 2 is placed on the Class I and Class II water quality class boundary [9]. No statistically significant difference was found between the stations by one-way variance analysis (ANOVA) and a Tukey multiple comparison test applied

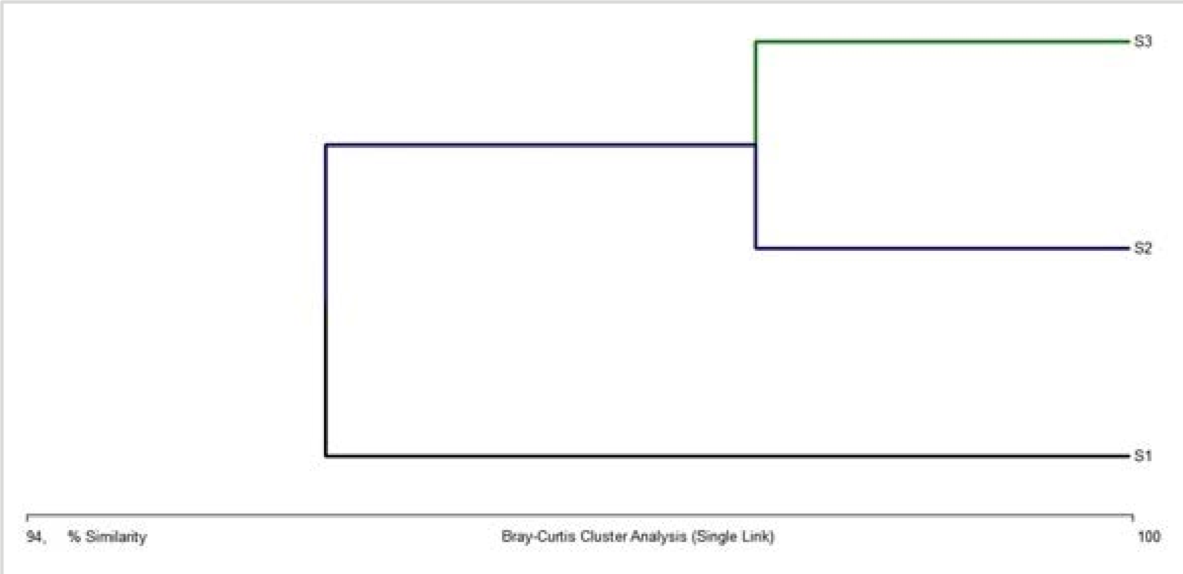

Fig. 3. Dendrogram of sites determined by analysis of environmental data using the Bray–Curtis similarity index.

to all environmental parameters ($p > 0.05$). Phosphorus is the major pollutant for streams passing through settlements. The possible phosphorus sources from hazelnut sites and the residential areas around site 2 contaminate the stream. While TP was measured as 0.021 mg L^{-1} in site 2, in the downstream TP was 0.012 mg L^{-1} due to aquatic macrophytes removing some of the nutrients in the water? The TP was measured as 0.018 mg L^{-1} in the upstream area because there are fewer agricultural areas in upstream areas and an absence of settlement areas. It is reported the trophic structure of aquatic ecosystem has oligotrophic character when it is below the limit value 25 μg L^{-1} as to TP in rivers and streams. This character is called as mesotrophic when it is in the range the limit value 25–75 μg L^{-1} according to the literature [29]. The trophic status of our study area is oligotrophic according to the average annual TP value (17 μg L^{-1}). It shows mesotrophic character in terms of maximum value (32 μg TP L^{-1}). In cluster analysis, site 1 is divided into a separate branch (Fig. 3). A stone quarry operation at site 1, river bed construction work at site 2 and domestic and agricultural inputs at the downstream zone of Turnasuyu Creek have caused occasional water contamination. However, Turnasuyu Creek has a "very good" water quality class according to physicochemical parameters. The edaphic, geological and climatological characteristics of the river basin directly and/or indirectly affect the natural structure and ecological diversity of the water. Agricultural and domestic anthropogenic effects in the Turnasuyu Basin may adversely affect the quality of water in the future. In addition, lack of adequate rainfall in recent years in Turkey affects the ecological structure of surface waters negatively.

The chl-a, found in all pigmented algae, gives information about planktonic algal biomass in surface water. In the present study, the concentration of suspended chlorophyll-a was recorded in the range of 0.31–0.60 μg L^{-1}. The average chl-a concentration was 0.49 μg L^{-1} and the algal productivity cannot be said to be very high. This is in fact directly related to low nutrient concentration in the stream. The total *P* concentration, which is the most important nutrient for eutrophication, was <25 μg L^{-1}. This suggests that there is no nutrient-related degradation in the stream and that the stream does not carry the risk of eutrophication. Turnasuyu Creek has an oligotrophic character according to the concentration of suspended chl-a (<10 μg L^{-1}) [29].

The algal diversity and intensity in Turnasuyu Creek's epilithon also showed temporal and spatial fluctuations. The relative abundance and species composition of epilithic algae have changed by the effects of environmental factors. The epilithic algal community of 124, 130 and 145 taxa was recorded in sites 1, 2 and 3, respectively. The benthic algal community at site 3, which is the most abundant, covers 36% of all algae. It has been reported that the abundance of periphyton in the rivers is greatly affected by the light, nutrient and flow regime [30,31]. Hydrological and climatological properties, especially environmental factors, such as light, temperature, rainfall, turbidity and flow rate, and nutrients have significantly influenced the composition and density of the epilithic algae communities in the present study. Benthic algae are considered resistant to environmental and pollution changes due to their ability to attach to substrates [32]. Diatoms, the most important element of phytobenthos and which also contains indicator species, are from the freshwater benthic organism group which is the most affected by environmental variables [33]. The diatoms in the phytobenthic algae community accounted for 51% of the total community in Turnasuyu Creek. Generally, diatoms are the most common group of benthic algae in rivers. Benthic diatoms are one of the main organisms for determining the ecological quality of water resources according to WFD. Under Turkey's regulations, phytobenthos are used in the monitoring of ecological status of surface water bodies [9,10]. Therefore, as an ecologically based approach, it is quite reasonable to use algae containing bioindicator species in the assessment of water quality.

The diatoms algae constitute 50% of Turkey's total freshwater algal flora [34]. The diatoms were the dominant algae group in all seasons, and in all the stations we surveyed in the Turnasuyu Creek epilithon. As shown in Table 2, the frequency index of the diatoms was calculated as 82%, 75% and 80%, respectively, from upstream to downstream. *A. minutissimum*, *C. affinis*, *E. minutum*, *F. crotonensis*, *H. arcus* and *R. sinuata* species were recorded at high frequencies at all stations. Again, *M. varians* and *U. ulna* species were recorded at high frequencies at site 2 and site 3. These species (Table 3) are the most common indicator species in xenosaprobic and α-mesosaprobic zones [35,36]. The common and dominant indicator species of Turnasuyu Creek, which is of an alkaline character, were neutral-alkaliphilic in general and oligohalob-indifferent in salinity preferences [25]. The green pigmented algae are the subdominant group after the dominant diatoms in the epilithic algal community: green algae (21%), blue-green algae (14%) and charophytes (10%). The filamentous algae (*Oscillatoria limosa*, *O. tenuis*, *Potamolinea aerugineo-caerulea*, *Pseudanabaena catenata*, *Pseudanabaena limnetica*, *Oedogonium* spp., *Ulothrix zonata*, *Spirogyra* spp.) in these algal groups emerged as common species in Turnasuyu Creek. It has been reported that such filamentous algae species represent special regions of some river basins with high agricultural activity [37]. The blue-green algae (92%), euglenoids (83%), chlorophytes (89%) and charophytes (78%) which is highly tolerant to organic pollution, recorded in site 3 have more species diversity in the downstream region than all other sites. Algae (*Euglena*, *Oscillatoria*, *Chlamydomonas*, *Scenedesmus*, *Chlorella*, *Navicula*, *Nitzschia*, *Stigeoclonium*, *Synedra* (*Ulnaria*), *Ankistrosdesmus*), which are organic pollution indicators, were recorded at this station [26]. However, *Ulnaria ulna* is the only type of algae found intensively in these species. The pollution index value of this species was 2. The organic pollution level of Turnasuyu Creek was very low, due to a Palmer's Pollution Index value of less than 15.

In streams of the Eastern Black Sea River Basin, similar to our study area; it has been reported that there are abundant diatoms such as *Encyonema minutum* and *Didymosphenia geminata*, blue-green algae such as *Oscillatoria limnetica* and green algae such as *Cladophora* sp. in the Şana Stream epilithon [38]. In Yanbolu Stream, *Hannaea arcus*, *Cymbella minuta*, *D. geminata* and *U. ulna*; *Spirogyra* sp. from green algae, *Oscillatoria* spp. from blue-green algae (especially in summer and autumn) are the most abundant taxa [39]. In the epilithic algal flora of Pazarsuyu Stream, *E. minutum*, *Navicula radiosa* and *U. ulna* were recorded as dominant [7]. In other studies, as in our present study, Euglenophyceae species were not important in epilithic algal flora.

The climate has a strong influence on the algal diversity. Temperature and elevation are seen as the most critical factor for algal communities [40]. Algae species diversity is low in high mountainous regions in the Black Sea Region. In these areas, green algae with diatom algae are foreground [1,40–42]; while diatoms are the dominant algae group in coastal regions. However, the diversity of benthic algae in the rivers of the Black Sea Region is not as rich as in our study area [6,7,38,39,43–45]. A total of 631 diatom species have been recorded in freshwater algae of Turkey [46]. The most common and abundant diatoms recorded in the surveys belong to the species *Navicula, Nitzschia, Surirella* and *Cymbella*. In Turnasuyu Creek, nine species belonging to *Navicula* genus, eight species belonging to *Nitzschia* genus, seven species belonging to *Cymbella* genus and three species belonging to *Surirella* genus were recorded. This number does not include taxons that were previously included in these genera but differ in today's systematic category (e.g., *Encyonema*). Within the Cimil Stream epilithic algae, the abundance of species belonging to these genera (*Cymbella*, *Navicula*, *Nitzschia*, *Surirella*) is remarkable [43]. The Cimil Valley and the Turnasuyu Valley, both in the Eastern Black Sea River Basin, are similar in ecological characteristics.

Benthic algae react to a wide variety of pollutants quickly. They provide potentially useful early warning signals for worsening or deteriorating water quality conditions. Since these are primary producers at base of the aquatic food web, algal indicators provide unique data on the health of the aquatic ecosystem. Diatom populations are extremely sensitive to natural changes in abiotic factors, including current and nutrient changes. It is well established that longitudinal variation in these and other physiochemical factors significantly influence benthic communities [47]. Diatoms are important in global cycling of silica and carbon, maintaining fisheries, and also maintaining a dynamic population of varying size [48]. From blue-green algae; *Oscillatoria* have α-mesosaprobic species and *Phormidium* have β-mesosaprobic species. Of these taxa, *O. limosa* and *O. tenuis* are the ones with the highest tolerance to organic pollution. The blue-green algae of *O. limosa*, *O. tenuis*, *Planktothrix agardhii* and *Pseudanabaena limnetica* in the epilithic algal communities of Turnasuyu Creek were recorded widely, especially in station 3. In general, these taxons are cosmopolitan, pollution-tolerant and organisms of β-α mesosaprobic conditions [35]. Some algal species that are planktonic in water (e.g., *P. agardhii*, *Planktothrix rubescenes*) are sporadically mixed into benthic flora. This may be due to the fact that water is less turbulent on the banks of the stream where the stone samples are taken and the water plants slow the speed of the water. Similar algae were widely recorded in the downstream of Cimil Stream [43]. A survey conducted at Pazarsuyu Stream, near Turnasuyu Creek, reported that the stream trophic structure was mesotrophic and moderately polluted (β-mesosaprobity) – heavily polluted (α-mesosaprobic) [7]. Kelly [49] reported that *A. minutissimum*, *C. placentula*, *C. affinis* and *U. ulna* are taxa that are frequently found in bloom, in freshwaters especially in streams. *A. minutissimum* is a benthic, alkaliphilic, α-mesosaprobic (severe organic pollution), eurythermic and cosmopolitan species [36,50,51] with low pollution and is widespread in clean waters [52]. It is reported that *A. minutissimum* is rarely seen in acidic mountain waters, which are predominant in the upper parts of the oligo/mesotrophic (clean/polluted) rivers [53,54]. *A. minutissimum*, which is generally found in environments with a first quality water feature, has been recorded in all seasons and stations in the present study. *C. affinis*, one of the common diatom species in Turnasuyu Creek, is an alkaline species. It has been reported that this species is predominant in clean waters, the indicator type for good water quality class [55]. The genus *Encyonema* is regarded as tolerant to eutrophication. However, *E. minutum* is a species preferring oligotrophic waters containing medium electrolyte [16]. It is a pollution-sensitive species that develops in the less-polluted streams [56]; epilithic and epiphytic communities, at a pH of about 7, with low phosphorus and conductivity [49]. *E. minutum* is classified as a species susceptible to organic pollution. This is a very common and abundant species in our study area. *Fragilaria capucina* is an ecological indicator of oligotrophic and oligo-mesotrophic conditions [2]. *U. ulna*, a tolerant species, was found to be a pollution tolerant species in each of the sampling stations. Van Dam et al. [2] and Lange-Bertalot [50] found that this species is very tolerant of pollution and is an indication that shows environmental conditions ranging from the oligosaprobic-α-mesosaprobic region to the polysaprobic region. Szczepocka and Szulc [57] and Bere and Tundisi [58] reported that *U. ulna* species is an organic pollution tolerant species. It is also stated that this species is frequently found in water rich in nutrients but with inadequate oxygen [59]. One of the most widely recorded diatoms is *Hannaea arcus*. This species is less tolerant of organic pollution and prefers neutral or alkaline conditions with relatively low nutrient concentrations. *Hannaea* populations are found in fast-flowing mountain streams, in oligotrophic, neutral (≥ 6.5) and low-nitrate environments [20]. *H. arcus* is a rheobiontic species in fast flowing streams [60]. *Didymosphenia geminata*, an invasive diatom species, is usually found in high lands and in northern regions. Often it is observed in oligotrophic water, but there is evidence that it can also be found in high nutrient environments. It spreads in subarctic and temperate conditions of Asia [61]. This species was recorded at all stations of our study area at high density, especially in spring (April and May). This species is recorded in Şana Stream [38], Yanbolu Stream [39] and Cimil Stream [43] from the Eastern Black Sea Region and in Ilıca Stream [44] and Melet River [6] from the Middle Black Sea Region. A study conducted in the Aragvi River in Georgia reported that species diversity from downstream to the upper areas have increased, and have more of a species diversity than most rivers in the Black Sea Region. The inverse relationship between two dominant algal groups, diatoms and green algae is also indicated [1]. The inverse relation between diatoms and green algae was also observed in Turnasuyu Creek. The diversity of green algae and conjugating green algae recorded in the freshwater of the mountainous areas of the Aragvi River is similar to the species in our study area. *Oedogonium* species from filamentous green algae generally develop better in alkaline systems [32]. This species has been recorded in all seasons in our study. However, since it is difficult to identify *Oedogonium* species by reproductive structures, it is difficult to identify morphological species. For this reason, *Oedogonium* was recorded at only the genus level. In general, dominant species in our field of work are cosmopolitan and pollution sensitive species. The system supports the development of diatoms that prefer clear waters, so there are taxa favoring oligotrophic and oligo-mesotrophic conditions. Increasing green alga species diversity starting from mid-summer and continuing in the first month of autumn, especially the increase in filamentous algae in the third station, is directly related to light, temperature and nutrients.

5. Conclusion

Turnasuyu Creek has a structure of temperate, oxygenated, freshwater, clean and alkaline water that is affected by low to moderate organic pollution according to the bioindication method. When the ecological characteristics of predominant algal species in Turnasuyu Creek were examined, in general, it was observed that there are cosmopolitan species preferring circumneutral pH and pH > 7. The species diversity of the present study is similar with those studies carried out in streams at the temperate climate zone. The species diversity has shown temporal and spatial changes. There are species that live in xenosaprobic-olisaprobic-β-mesosaprobic and α-mesosaprobic regions from upstream to downstream areas. Turnasuyu Creek has low organic pollution according to indicator species, environmental parameters and indices. It has oligo-mesotrophic trophic structure. The present study, as a first of its nature carried out at Turnasuyu Creek, located in one of the green valleys of Turkey, will hopefully contribute to future studies, particularly monitoring and assessing the impact of climate variability on species diversity and water quality.

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