

# Seasonal Variations of Water Quality Parameters and Algal Flora of Tundzha (Tunca) River (Edirne, Turkey)

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## Abstract

In this study which was performed in order to determine the seasonal variations of water quality parameters and algal flora of Tundzha River, samplings were made monthly from 5 different stations along the river. A total of 138 taxa from Chlorophyceae (65 taxa), Bacillariophyceae (46 taxa), Euglenophyta (13 taxa) and Cyanophyta and Charophyta (7 taxa) were found to represent the algal flora of the river. Diatoms were recorded to be the dominant group throughout the year in terms of biovolume. Station I was the richest station during the whole study in terms of species diversity and composition. The maximum abundance of phytoplanktonic community within this station was 3,459,313 cells·L<sup>-1</sup>, and Station IV was found to be richest station in terms of biovolume, with 2028.8 µg·L<sup>-1</sup>. The water quality of the river was found to be close to the 2nd and 3rd quality levels. 2nd and 3rd, and 1st and 3rd stations were found to be most similar to each other in terms of floristic compositions biovolume, respectively.

## Keywords

Tundzha River, Physico-Chemical Parameters, Phytoplankton, Algae Composition, Biomass

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## 1. Introduction

From the beginning of plankton research [1], the main focus of interest has been given on lentic waters, especially large lakes. The ecological and functional roles of potamoplanktons in fluvial ecosystems were first described in the early studies [2]-[4] whose results have remained until today without any validation. Later on,

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Welch reported that the phytoplankton assemblages in rivers were much modified with respect to lakes [5].

Streams and rivers provide habitats which are very different from those in lakes, for they are subject to changes along their length associated with depth, rate of flow, geology of the land surface and of the stream bed, salt concentration, turbidity, etc., all these being further complicated by seasonal changes [6]. Phytoplanktons are unable to maintain populations in fast-flowing streams, but can become abundant in slowly moving rivers and backwaters where their doubling rates exceed downstream losses due to current [7]. River and lake phytoplankton are subject to different factors. For instance, phytoplankton load in lakes is subject to nutrient load in deep lakes but in shallow lakes, stochastic meteorological events are of major importance. On the other hand, riverine phytoplankton are mainly related to light availability and time of travel instead of nutrient load [8].

Although studies on potamoplankton dated back to late 1890s, studies in Turkey started by the mid 1980s [9]-[11]. There are some early studies on segment of Tunca River in Bulgaria [12] [13], but no algological study has been performed so far within the Turkey. Part of the river forms meanders with a slow water current in a wider river bed.

We aim in this study i) to determine the composition, biomass and diversity of algal flora of Tunca River in Turkish Thrace, ii) to reveal longitudinal distribution patterns of present taxa along the river, and iii) to determine physicochemical factors affecting the algal composition of the river.

## 2. Material and Methods

### 2.1. Study Area

Tundzha (Tunca) River is the biggest segment of Maritza River who reaches Aegean Sea at Saros Bay which is classified as B class wetland according to Ramsar Pact. The river enters Turkey in Suakacağı Village of Lalaşa-Edirne, after travelling about 350 km throughout Bulgarian land. The length of Turkey segment of the river is 54.7 km and the mean flow rate is 18.38 m<sup>3</sup>/sec. The river meets with Maritza River to the south of Edirne city centre. The areas surrounding the river, as in Thrace region in general are used for corn, sun flower, crop, fruit, vegetable and particularly rice cultivation. Local woodland and scrubby areas along the river also exist. A preliminary study was performed and 5 stations were determined to represent the part of the river in Turkey from the Bulgarian border until it meets Maritza River (Figure 1). Water and phytoplankton samples were taken from the 5 stations twice a week from June 2002 to October 2003 and once a month from November 2002 to May 2003.

### 2.2. Sampling

A Ruttner water sampler was used to obtain water samples just below the surface of the water body in order to determine some physico-chemical properties of the river. Water temperature, Dissolved Oksigene, pH and con-

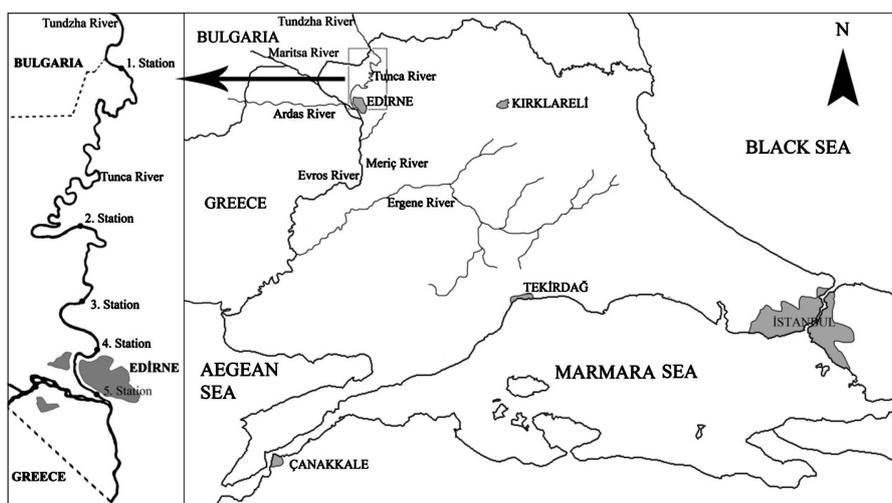


Figure 1. The map to Tundzha River and the stations selected along the study part of the river.

ductivity were measured on site during samplings using field type equipments (Lovibond sensodirect oxi 200, pH 200 and Con 200) and PO<sub>4</sub>-P, NO<sub>3</sub>-N, NO<sub>2</sub>-N, total hardness, COD and BOD were measured in laboratory in accordance with APHA-AWWA-WPCF methods [14]. Chlorophyll-*a* was analyzed according to Nusch [15]. Winkler method was applied in dissolved oxygen determinations [16]. BOD and COD values were measured using methods given in Golterman [17].

Sampled phytoplankton specimens were identified by investigation of temporary preparations. For this purpose, water samples were filtered from Whatman GF/A (90 mm diam., 1.6 µm pore size) paper with the help of a water trompe and dissolved in 10% glycerine. An Uthermol counting chamber was used to calculate the organism number per liter [18] [19]. Biovolumes were measured using geometric or combined forms formulae according to Standard Operating Procedure for Phytoplankton Analysis [20]. For the identification of algal species Husted, Cleve-Euler, Pestalozzi, Prescott, Komarek and Fott, Krammer and Lange-Bertalot were used [21]-[29]. And also all the species are checked in algaebase cite [30].

### 2.3. Statistical Analysis

A Bray-Curtis analysis was performed to reveal similarities, if any, among stations based on algal species diversity and abundance [31]. Abiotic variables were correlated with main phytoplankton attributes using non-parametric Spearman's correlation coefficients. Differences in all variables were tested using a non-parametric Kruskal-Wallis ANOVA median test (KW). Differences at the <0.05 level were accepted as significant. Also, to compare stations, non-parametric statistics (the Mann-Whitney U test) were used. Species richness was considered to be the number of taxa present in each sample. Biological diversity (H') was calculated by the Shannon and Weaver [32].

## 3. Results

### 3.1. Water Quality Parameters

The results of Physico-chemical analysis showed that the highest pH and dissolved oxygen values were measured in Station 1 in spring and winter months, respectively. The Cl content appeared to be high in station III in spring and Biological Oxygen Demand in station V in winter. Station V was also characterized with the highest Phosphate value in summer months. NO<sub>2</sub>-N and NO<sub>3</sub>-N was measured at high levels in stations III (in autumn), respectively. The results also revealed that Chlorophyll *a* was measured in its highest value in station IV in summer. The mean results of all analysis are given in **Table 1**.

Nitrate-N was found to be negatively correlated with water temperature, electrical conductivity and biomass and no significant relation was found between other physico-chemical variables ( $P < 0.05$ ). The comparison of stations based on abiotic factors revealed that all stations were similar ( $P < 0.01$ ).

### 3.2. Phytoplankton Species Diversity

The taxonomic evaluation of all samples obtained showed that a total of 138 taxa lived in the river (**Table 2**). Station I was the richest in terms of species diversity with 118 taxa while station 5 was the least diverse station with 87 taxa (**Table 3**). Chlorophyceae was found to be represented with the highest number of species (65 taxa) followed by Bacillariophyceae (46 taxa), Euglenophyta (13 taxa) and Cyanophyta and Charophyta (7 taxa). Since none of the 7 taxa of cyanophytes showed an extreme growth during the study period, they never were among the dominating or subdominating taxa and thus did not lead to formation of water bloom.

Chlorophyta, which was represented with 57 taxa in station I (richest) and 39 taxa in station V (poorest), appeared to be the dominant group in the phytoplankton community in the river. On the other hand, diatoms constituted the second dominant group and all stations were similar in terms of their diatom compositions. Although pennant diatoms were rich in terms of species diversity, Cyclotella species of centric diatoms were found to have the highest cell counts in all stations, particularly in spring, summer and autumn months.

### 3.3. Abundance and Volume Biomass

The highest cell counts were obtained in the sample from 1th station (3,459,313 cells·L<sup>-1</sup>) whereas the lowest counts were obtained from samples of 2th (1,713,312 cells·L<sup>-1</sup>) and 5th stations (1,815,672 cells·L<sup>-1</sup>). Centric diatoms were highly abundant in the samples from the river (**Figure 2**). Cyclotella species, in particular, were

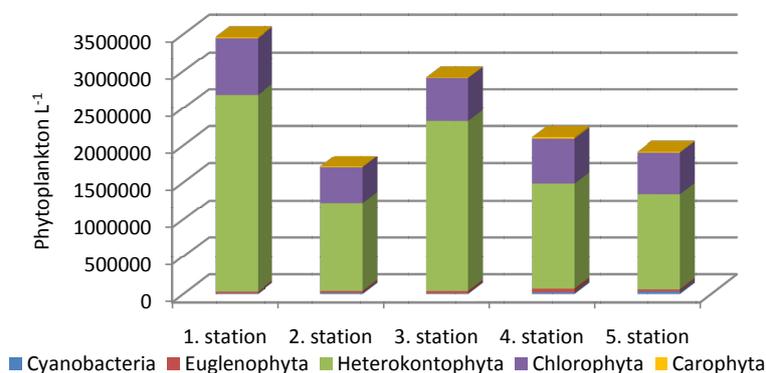


Figure 2. The number of planktonic algal counts with respect to stations.

Table 1. The mean values of some Physico-chemical parameters in Tundzha River.

	Water Temperature (°C)	Conductivity (µmho/cm)	pH	Diss. Oxygen (mg/l)	Hardness (FS)	NO <sub>3</sub> -N (mg/l)	NO <sub>2</sub> -N (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	BOD	C.O.D	Chlorophyll_a	
Summer	Ith Station	24.17	0.65	8.59	8.25	40.53	2.13	0.00	2.42	0.11	2.72	21.17	64.97
	IIth Station	24.42	0.77	8.25	9.97	44.30	1.50	0.01	2.78	0.06	2.45	10.83	21.66
	IIIth Station	24.25	0.80	8.22	8.15	47.67	2.55	0.02	2.96	0.08	3.34	12.00	74.00
	IVth Station	25.08	0.81	8.29	9.14	49.27	2.94	0.09	3.02	0.17	4.92	18.67	113.74
	Vth Station	26.08	0.79	8.46	8.74	49.38	3.60	0.30	2.99	0.18	3.30	24.00	85.25
Autumn	Ith Station	14.00	0.52	8.22	10.68	28.80	11.41	0.10	2.29	0.13	6.05	30.00	17.76
	IIth Station	15.00	0.56	8.08	9.97	30.88	9.24	0.08	2.49	0.13	5.69	22.60	17.02
	IIIth Station	15.50	0.58	8.12	10.25	30.36	11.73	0.10	2.51	0.13	5.45	24.40	12.43
	IVth Station	15.80	0.58	8.11	9.44	30.08	11.42	0.16	2.55	0.15	4.54	24.20	12.65
	Vth Station	16.10	0.61	8.03	9.20	29.92	10.84	0.15	2.51	0.15	3.54	25.40	13.09
Winter	Ith Station	4.33	0.42	8.32	13.58	27.33	9.00	0.05	2.31	0.06	3.73	23.33	4.59
	IIth Station	4.00	0.42	8.37	11.23	26.33	6.86	0.06	2.18	0.06	4.43	36.33	5.18
	IIIth Station	4.50	0.42	8.39	11.29	26.80	8.56	0.07	2.35	0.06	5.27	26.33	3.99
	IVth Station	4.00	0.42	8.40	11.29	26.67	8.15	0.07	2.40	0.07	6.03	38.00	2.96
	Vth Station	4.17	0.40	8.40	11.66	27.13	7.09	0.03	2.39	0.07	6.20	27.33	3.41
Spring	Ith Station	11.17	0.58	8.64	12.12	33.93	9.18	0.08	3.44	0.07	4.50	38.33	10.85
	IIth Station	11.67	0.57	8.68	7.96	33.00	7.34	0.04	3.18	0.05	3.95	37.67	11.43
	IIIth Station	11.17	0.57	8.68	7.96	32.33	8.93	0.04	3.27	0.05	5.43	43.00	12.23
	IVth Station	11.50	0.57	8.65	7.45	31.93	9.78	0.04	3.24	0.05	6.05	39.67	12.75
	Vth Station	11.67	0.58	8.66	7.20	32.93	8.96	0.02	3.26	0.06	5.56	33.67	11.97

obtained with high biomass values in all stations by the beginning of spring season. Diatoms appeared to be the dominant group in terms of cell counts followed by green algae as the second dominant group in the river. Other algal groups were recorded with low abundance values (Table 4). Most of the algal species found in the Bulgarian segment of the river were also determined in the present study except Ceratium, Peidinium, Dinobryon and Stephanodiscus [13].

**Table 2.** The list of the planktonic algal species obtained in Tundzha River during the study period.

	Stations				
	I	II	III	IV	V
Empire Prokaryota					
Kingdom Eubacteria					
Subkingdom Negibacteria					
Phylum Cyanobacteria					
Class Cyanophyceae					
<i>Anabaena</i> sp.	+	+	+	-	-
<i>Aphanizamenon</i> sp.	+	+	+	+	+
<i>Merismopedia</i> sp.	+	+	+	+	+
<i>Microcystis</i> sp.	-	-	+	-	-
<i>Oscillatoria limosa</i> Agardh	+	+	+	+	+
<i>O. articulata</i> Gardner	+	-	-	-	-
<i>Oscillatoria</i> sp.	+	+	+	+	-
Empire Eukaryota					
Kingdom Protozoa					
Phylum Euglenophyta					
Class Euglenophyceae					
<i>Euglena acus</i> (O. F. Müller) Ehrenberg	+	-	-	-	-
<i>E. elongate</i> Schewiakoff	-	-	+	+	-
<i>E. gibbosa</i> Schiller	+	-	-	+	-
<i>E. limnophila</i> Lemmermann	-	-	-	+	-
<i>E. polymorpha</i> P. A. Dangeard	-	-	+	+	+
<i>E. tuberculata</i> Swirenko	+	-	-	+	-
<i>E. viridis</i> (O.F.Müller) Ehrenberg	-	+	-	-	-
<i>Phacus acuminatus</i> Stokes	+	+	-	-	-
<i>P. helikoides</i> Pochmann	-	+	-	-	-
<i>P. longicauda</i> (Ehrenberg) Dujardin	+	-	-	-	-
<i>P. orbicularis</i> K. Hübner	-	-	+	-	-
<i>P. tortus</i> (Lemmermann) Skvortzov	+	-	-	-	-
<i>Trachelomonas</i> sp.	+	+	+	+	+
Empire Eukaryota					
Kingdom Chromista					
Phylum Heterokontophyta					
Class Bacillariophyceae					
<i>Cocconeis placentula</i> Ehrenberg	+	+	+	+	+
<i>Gomphonema truncatum</i> Ehren.	+	+	+	+	+
<i>Cymbella cistula</i> (Ehren.) Kirchner	+	+	+	+	+
<i>C. tumida</i> (Brébisson) van Heurck	+	+	+	+	+

## Continued

<i>Rhoicosphenia curvata</i> (Kützing) Grun.	+	+	+	+	+
Class Fragilariophyceae					
<i>Asterionella formosa</i> Hassall	+	+	+	+	+
<i>Fragilaria crotonensis</i> Kitton	+	+	+	+	+
<i>Fragilaria virescens</i> Ralfs	+	+	+	+	+
<i>Diatoma vulgare</i> Bory de Saint-Vincent	+	+	+	+	+
<i>Ulnariaacus</i> (Kütz.) Cambra & Ector	+	+	+	+	+
<i>Ulnaria ulna</i> (Nitzsch) P. Compère	+	+	+	+	+
<i>Caloneis amphisbaena</i> Cleve	+	+	+	+	+
<i>Gyrosigma acuminatum</i> (Kützing) Rab.	-	-	+	+	+
<i>G. attenuatum</i> (Kützing) Cleve	-	-	+	-	-
<i>G. macrum</i> (Smith) Cleve	+	+	+	+	+
<i>Navicula</i> Ehrenberg	+	+	+	+	+
<i>N. cuspidate</i> Kützing	+	+	+	+	+
<i>N. viridula</i> Kützing	+	+	+	+	+
<i>N. expansa</i> Hagelstein	-	+	-	-	-
<i>Navicula</i> sp.	+	+	+	+	+
<i>Neidium affine</i> (Ehrenberg) Pfizer	+	+	+	+	+
<i>Pinnularia acuminata</i> Smith	+	+	+	+	+
<i>P. viridis</i> Ehrenberg	+	+	+	+	+
<i>Amphora ovalis</i> Kützing	+	+	+	+	+
<i>Hantzschia amphioxys</i> Cleve & Grun.	+	+	+	+	+
<i>Nitzschia acicularis</i> (Kützing) Smith	+	+	+	+	+
<i>N. amphibian</i> Grun.	+	+	+	+	+
<i>N. flexa</i> Schumann	+	+	+	+	+
<i>N. elongate</i> Hassall	+	+	+	+	+
<i>N. palea</i> (Kützing) W. Smith	+	+	+	+	+
<i>N. parvula</i> W. Smith	+	+	-	-	-
<i>N. sigmoideae</i> W. Smith	+	+	+	+	+
<i>N. hungarica</i> Grun.	+	+	+	+	+
<i>N. obtuse</i> Smith	-	+	+	-	-
<i>Nitzschia</i> sp.	-	-	-	+	+
<i>Epithemia adnata</i> (Kützing) Ross	+	+	+	+	+
<i>Epithemia sorex</i> Kützing	+	+	+	+	+
<i>Mastogloia smithii</i> Thwaites	+	+	+	+	+
<i>Cymatopleura elliptica</i> Smith	+	+	+	+	+
<i>C. solea</i> W. Smith	+	+	+	-	-
<i>Surirella robusta</i> Ehrenberg	+	+	+	+	+
<i>S. ovalis</i> Brébisson	+	+	+	+	+
Class Coscinodiscophyceae					
<i>Melosira varians</i> Agardh	+	+	+	+	+
<i>Aulacoseira italica</i> (Ehrenberg) Simonsen	+	+	+	+	+
Class Mediophyceae					

## Continued

<i>Cyclotella meneghiniana</i> Kütz.	+	+	+	+	+
<i>Cyclotella</i> sp.	+	+	+	+	+
Empire Eukaryota					
Kingdom Plantae					
Phylum Chlorophyta					
Class Chlorophyceae					
<i>Pandorina morum</i> (O. F. Müller) Bory	-	-	-	+	+
Class Trebouxiophyceae					
<i>Actinastrum hantzchii</i> Lagerheim	+	+	+	+	+
<i>Chlorella elipsoidea</i> Gerneck	-	-	+	+	-
<i>C. mirabilis</i> Andreyeva	-	-	-	-	+
<i>C. oocystoides</i> Hindak	-	+	-	-	+
<i>C. vulgaris</i> Beyerinck	+	+	+	+	+
<i>Crucigeniella saugeii</i> Komárek	+	-	-	+	-
<i>C. rectangularis</i> (Nägeli) Komárek	+	+	+	+	+
<i>Crucigenia tetrapedia</i> Kuntze	+	+	-	-	+
<i>Golenkiniopsis longispina</i> Korshikov	+	+	+	+	-
<i>Keratococcus bicaudatus</i> Petersen	+	-	-	+	-
<i>Lagerheimiagenevensis</i> Chod.	+	+	+	+	+
<i>L. wratislaviensis</i> Schröder	-	-	-	-	+
<i>Oocystis apiculata</i> West	+	-	-	-	-
<i>O. marssonii</i> Lemmermann	+	-	-	-	-
<i>O. parva</i> West	+	+	+	+	-
<i>Oocystis</i> sp.	+	+	+	+	+
<i>Dictyosphaerium</i> sp.	+	+	+	+	+
<i>Tetrachlorella incerta</i> Hindák	+	+	+	+	+
<i>Closteriopsis longissima</i> Lemm.	+	+	+	+	+
<i>Chlorobion brauni</i> (Nägeli) Komárek	+	-	+	-	-
<i>Coelastrum astroideum</i> De Notaris	+	+	+	+	+
<i>C. microporum</i> Nägeli	+	+	+	+	+
<i>C. morus</i> W & G West	+	+	+	+	+
<i>Golenkinia radiata</i> Chod.	+	+	+	-	-
<i>Pediastrum boryanum</i> Meneghini	+	+	+	+	+
<i>P. duplex</i> Meyen	+	+	+	+	+
<i>P. simplex</i> Meyen	+	+	+	-	-
<i>P. tetras</i> (Ehrenberg) Ralfs	+	+	+	+	+
<i>Tetrademus major</i> Fott & Komárek	-	+	-	-	-
<i>Ankistrodesmus bibrainus</i> Korshikov	+	-	+	-	-
<i>Korshikoviella gracileps</i> Silva	+	-	-	-	-
<i>Kirchneriella aperta</i> Teiling	+	+	+	-	-
<i>K. lunaris</i> (Kirchner) K. Möbius	+	+	-	-	-

## Continued

<i>K. contorta</i> (Schmidle) Bohlin	+	+	+	+	+
<i>Kirchneriella</i> sp.	+	+	+	+	+
<i>Monoraphidium arcuatum</i> (Korsh.) Hindák	+	+	+	+	+
<i>M. contortum</i> Kom-Legn	+	+	+	+	+
<i>M. griffithii</i> Kom-Legn	+	+	+	+	+
<i>M. minutum</i> Kom-Legn	+	+	+	+	+
<i>Scenedesmusacuminatus</i> (Lager.) Chod.	+	+	+	+	+
<i>S. acutus</i> Meyen	+	+	+	+	+
<i>S. armatus</i> Chodat	+	-	-	-	-
<i>S. bicaudatus</i> Dedusenko	+	+	+	+	-
<i>S. disciformis</i> Fott & Komárek	+	+	+	+	+
<i>S. ecornis</i> Chod.	-	-	+	-	
<i>S. intermedius</i> Chod	+	-	+	+	+
<i>S. magnus</i> Meyen	+	+	+	+	+
<i>S. opolinensis</i> Richter	+	+	+	+	+
<i>S. pecsensis</i> Dherk	+	+	+	-	-
<i>S. protuberans</i> Fritsch & Rich	-	-	+	-	-
<i>S. quadricauda</i> (Turpin) Brébisson	+	+	+	+	+
<i>S. quadrispina</i> Chod.	+	+	+	+	+
<i>S. spinosus</i> Chod.	+	+	+	+	-
<i>Schroederia antillarum</i> Komárek	+	-	+	+	-
<i>S. robusta</i> Korshikov	+	-	-	-	-
<i>Tetrastrum staugeniforme</i> (Sch.) Lemm.	+	+	+	+	+
<i>T. komarekii</i> Hindák 1977	+	+	+	+	+
<i>T. triangulare</i> (Chodat) Komárek	+	+	+	-	+
<i>Tetraedron minimum</i> Hansgirg	+	+	+	+	+
<i>T. caudatum</i> Hansgirg	+	+	+	+	+
<i>T. regulare</i> Kützing	+	+	+	-	-
<i>T. triangulare</i> Korshikov	+	+	+	+	-
<i>T. trigonum</i> Hansgirg	+	+	+	+	+
<i>Tetrademus wisconsinensis</i> Smith	+	+	+	+	-
Phylum Charophyta					
Class Conjugatophyceae					
<i>Closterium acutum</i> Brébisson	+	+	+	+	+
<i>Closterium lunula</i> Ehren. & Hemp.	+	+	+	+	+
<i>Closterium parvulum</i> Nägeli	+	+	+	-	-
<i>Cosmarium undulatum</i> Corda	+	+	+	+	-
<i>Cosmarium</i> sp.	+	+	+	+	-
<i>Staurastrum anatinum</i> Cook & Wills	+	-	-	-	-
<i>Staurastrum paradoxum</i> Meyen	+	+	+	-	-

**Table 3.** Number of species and relative number of species [%] determined in the plankton of the Tundzha River.

Groups/Stations	I. Station		II. Station		III. Station		IV. Station		V. Station	
	Σ taxa	%	Σ taxa	%	Σ taxa	%	Σ taxa	%	Σ taxa	%
Cyanophyceae	6	5.1	5	4.7	6	5.5	4	4.0	3	3.4
Euglenophyceae	7	5.9	4	3.8	4	3.6	6	6.1	2	2.3
[Diatoms]	[41]	[34.7]	[43]	[40.6]	[43]	[39.1]	[41]	[41.4]	[41]	[47.1]
Bacillariophyceae	5	4.2	5	4.7	5	4.5	5	5.1	5	5.7
Fragilarophyceae	32	27.1	34	32.1	34	30.9	32	32.3	32	36.8
Coscinodiscophyceae	2	1.7	2	1.9	2	1.8	2	2.0	2	2.3
Mediophyceae	2	1.7	2	1.9	2	1.8	2	2.0	2	2.3
Chlorophyta	57	48.3	48	45.3	51	46.4	44	44.4	39	44.8
Conjugatophyceae	7	5.9	6	5.7	6	5.5	4	4.0	2	2.3
Σ [138 taxa]	118	100	106	100	110	100	99	100	87	100

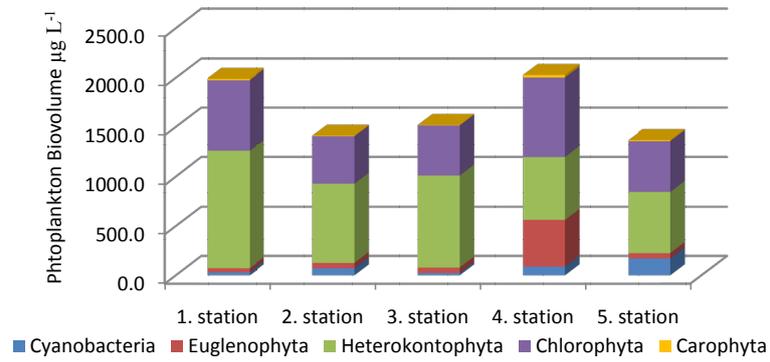
**Table 4.** Planktonic cell counts and biomass in Tundzha River.

Groups	Cells		Biomass	
	Per L	%	μg·L <sup>-1</sup>	%
Cyanophyceae	50,879	2.1	74.9	4.5
Euglenophyceae	79,953	3.3	135.8	8.2
[Diatoms]	[1,693,548]	[69.9]	[835.9]	[50.3]
Bacillariophyceae	21,805	0.9	15.4	0.9
Fragilarophyceae	237,436	9.8	277.1	16.7
Coscinodiscophyceae	67,839	2.8	226.1	13.6
Mediophyceae	1,366,468	56.4	317.3	19.1
Chlorophyta	562,093	23.2	605.0	36.4
Conjugatophyceae	36,342	1.5	11.4	0.7
Σ	2,422,816	100	1663	100

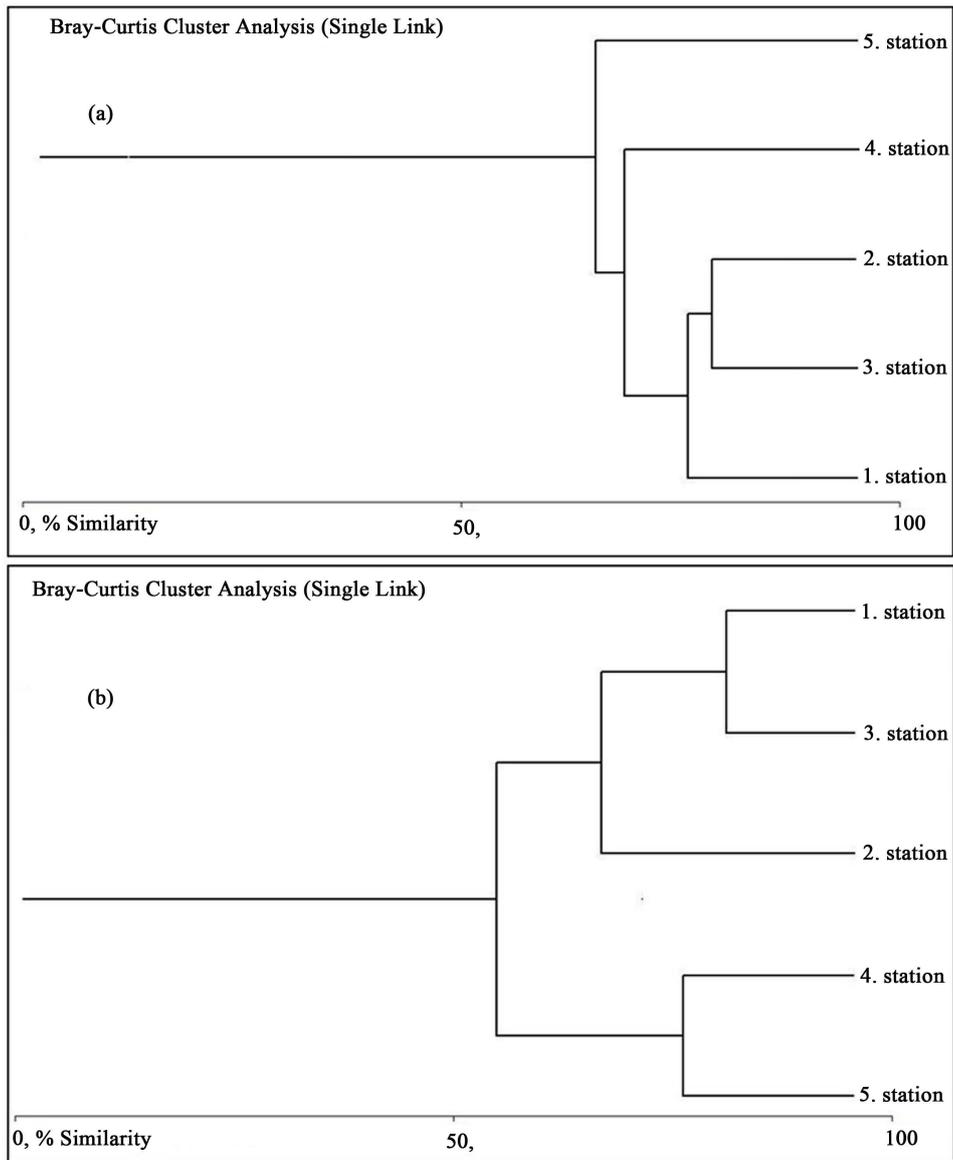
Differences in the biovolume of phytoplankton from the 5 sampling sites are illustrated in **Figure 3**. Diatoms are the prevailing group in samples from all localities except the 4th station where Chlorophyta was the dominant group. The biovolume of Euglenophyta members were measured to be highest in the 4th station (2028.8 μg·L<sup>-1</sup>) whereas it was the lowest in the 5th station (1366.8 μg·L<sup>-1</sup>).

When floristic compositions of all 5 stations were used to obtain a similarity index through the cluster analysis, the 2th and 3rd stations were found to have very similar floristic compositions and, although all stations revealed a somewhat same similarity, the 5th station was grouped to be the outgroup among the stations with the least similarity (**Figure 4(a)**). The cluster analysis based on biovolumes measured for each stations revealed that the 1th and 3th stations were the most similar ones to each other (**Figure 4(b)**).

The abundance of phytoplankton was significant, and was positively correlated with Chl-a and temperature ( $r = 0.77$  and  $r = 0.86$ , respectively  $P < 0.01$ ). The biovolume of Bacillariophyta was positively correlated with the species number ( $r = 0.71$ ,  $P < 0.01$ ). The estimates of algal biomass did not show any correlation with nutrients. Some water quality parameters were found to show a significant relationship with the dominant taxa. For example, DO concentration was correlated with the mean total number of *C. meneghiniana* and *M. varians* ( $r = 0.72$



**Figure 3.** Biovolume of phytoplankton (per Liter) of sampling sites.



**Figure 4.** Results of clustering analyses: (a) based on differences in the floristic composition of phytoplankton (Bray-Curtis distance); (b) based on differences in portions of main distinguished algal groups (Bray-Curtis distance).

and  $r = 0.61$ , respectively  $P < 0.05$ ). In addition, nitrate and phosphate were found to negatively correlated with biovolume ( $r = -0.71$  and  $r = -0.54$ , respectively  $P < 0.05$ ).

#### 4. Conclusions

It is well known that oxygen is consumed during decomposition of organic materials in waters and regain of the consumed oxygen is rather slow in surface waters [33]-[35], which is a fact naturally affecting organisms living here. The low productivity values measured in the 4th and 5th stations were concluded to be related with this pollution. The low  $\text{NO}_3\text{-N}$  values, despite the high measured nitrite, showed that nitrification process did not take place as a result of low oxygen values. The water quality of the river was found to be ranked in the II and III class according to the criteria of SKKY [36].

The plankton surveys in the river allowed us to provide a list of up to 136 taxa, which were of cosmopolitan distribution, characteristic for mesotrophic or eutrophic running waters. But the list of common and truly planktonic taxa is much less and few because the actual number of any planktonic taxa specific to river is low. The periodicity of phytoplankton the Tundzha River was influenced by complex interactions among allogenic and autogenic factors. Chlorophyta was the dominant group in the river throughout the study period in terms of species diversity and diatoms were the leading group in terms of biovolume.

In most large rivers, Bacillariophyceae blooms tend to occur in spring and fall, whereas a mixture of Chlorococcales and Bacillariophyceae appears during summer [37] [38]. The present Cyclotella bloom observed in Tundzha River from mid spring to mid autumn is a common phenomenon in other eutrophicated rivers as well. The varying abundances of these taxa in Tundzhariver in different seasons fit the classification of Descy (1987) in European rivers who reported that centric diatoms were dominant and green algae were abundant in summer in slow-moving, nutrient-rich large rivers.

Organisms with low tolerance to organic pollution, *i.e.* Nitzchiapalea (Kütz.) Smith, were determined in the river. In addition to Cyclotellameneghiniana (Kütz.), an indicator of mesotrophic waters, polluted water adapted organisms, Rhoicospheniaturvata (Kütz.) Grun. and Cocconeisplacentula (Ehr.) Cleve, preferring eutrophic water bodies were also found [39]. Naviculavirudula Kütz., an algal species preferring eutrophic lowland rivers is another tax a frequently determined during the study [40]. The representatives of Euglena, Navicula, Oscillatoria and Ulnaria found in the river are high tolerant species to pollution as reported by Şen [41]. The varying abundances of algal taxa in polluted sites are considered as indication of pollution here. The results revealed that species diversity of the genera within Euglenophyta showed an increase in the 4th station particularly in summer months as a result of increase in discharge of organic material originating from Edirne city centre accompanied with increased evaporation and agricultural water use. Moreover, Chlorophyll *a* content of this part of the river was also found to increase significantly.

When the phytoplankton biomass reached its maximum values, namely in summer season, Chlorophyll *a* also exhibited that it reached its maximum, in July and August. The high concentration of Chlorophyll *a* indicated high productivity, also noted in numerical abundance and biomass of phytoplankton. It is now accepted that in any river or flowing water, the amount of plankton increases downstream. In the present investigation, during early months of winter, the plankton is found to be at its minimum. This supports the hypothesis of Schroder who stated that the volume of plankton present in any stream was inversely proportional to the rate of the water current [42].

Coinciding with what Claps [43] pointed out, a reduction in algal population after the spring floods could be seen. Planktonic algae flora of the Tundzha River were affected in the same way by flood in spring. Similar conditions were also observed in Yeşilırmak River, Euphrates (Karasu) River and Meram Stream [44]. However, floods affected communities in different ways in the River Pampean in Argentina [45] (Solari and Claps, 1996).

Although the present results cannot be used for a retrospective comparison of former and current aspects of the river to put forward whether the species number and biomass change in time or not because no similar study has been performed in the Turkey segment of the river, the results coincide with that of studies performed in Bulgaria.

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