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Research Article

Evaluation of the Trophic Status of Karasu River (Erzincan, Türkiye) by Biodiversity Indices

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Abstract

This study focuses on seasonal and temporal variations of the biodiversity and composition of the phytoplankton community in Karasu River. The phytoplankton and water samples were collected bimonthly from a depth of 0.5-8 m during the period from January 2019 to July 2019 from five stations. Four diversity indices (Shannon-Wiener, Simpson, Margalef and Menhinick) were studied. MINITAB 15 Software was used to interpret the relationship between the indices. Average water temperature, dissolved oxygen, pH and electritrical conductivity values were measured as 19.43 °C, 7.9 mg L, 8.3 and 465 mS/cm, respectively. In this study, a total of 123 phytoplankton species were identified. Among these species, 106 species belonging to Bacillariophyta group, 10 species belonging to Chlorophyta group, 6 species belonging to Cyanobacteria group and 1 species belonging to Euglenophyta group were included. Throughout the study, Shannon-Wiener, Simpson Margalef, and Menhinick diversity indices were calculated as 1.83 H´, 11.53, 5.12 and 0.83 and respectively. As a result of this study, phytoplankton diversity indices and ecological status assessment based on water quality were not found to be compatible. However, introducing reference conditions for different cities can increase the usability of the indices thus we recommend expanded further studies.

Keywords: Shannon-Wiener, biodiversity indices, phytoplankton, Karasu River

Karasu Nehri (Erzincan,Türkiye)'nin Trofik Durumunun Biyoçeşitlilik İndeksleriyle Değerlendirilmesi

Öz

Bu çalışma, Karasu Nehri'ndeki fitoplankton kompozisyonunun ve biyolojik çeşitliliğinin mevsimsel ve zamansal değişimlerine odaklanmıştır. Fitoplankton ve su örnekleri Ocak 2019-Temmuz 2019 döneminde iki ayda bir 0.5-8 m derinlikten beş istasyondan toplanmıştır. Dört çeşitlilik indeksi (Shannon-Wiener, Simpson, Margalef ve Menhinick) incelenmiştir. Endeksler arasındaki ilişkiyi yorumlamak için MINITAB 15 yazılımı kullanılmıştır. Ortalama su sıcaklığı, çözünmüş oksijen, pH ve iletkenlik değerleri sırasıyla 19.43 °C, 7.9 mg/L, 8.3 ve 465 mS/cm olarak ölçülmüştür. Bu çalışmada toplam 123 fitoplankton türü tespit edilmiştir. Bu türlerden Bacillariophyta grubuna ait 106 tür, Chlorophyta grubuna ait 10 tür, Cyanobacteri grubuna ait 6 tür ve Euglenophyta grubuna ait 1 tür teşhis edilmiştir. Çalışma boyunca Shannon-Wiener, Simpson Margalef ve Menhinick çeşitlilik indeksleri sırasıyla 1.83 H´, 11.53, 5.12 ve 0.83 olarak hesaplanmıştır. Bu çalışma sonucunda fitoplankton çeşitlilik indeks değerleri ile Karasu Nehri'nin su kalitesine bağlı ekolojik durum değerlendirilmesi bir biri ile uyumlu olmadığı tespit edilmiştir. Ancak farklı şehirler için referans koşulların geliştrilmesi endekslerin kullanılabilirliğini artırabilir. Bu nedenle bu çalışmaların devam etmesini ve yaygınlaşmasını öneriyoruz.

Anahtar Kelimeler: Shannon-Wiener, biyolojik çeşitlilik indeksleri, fitoplankton, Karasu Nehri

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1. Introduction

Türkiye has very important inland water resources with its streams and lakes covering an area of approximately 10000 km^2. The Eastern Anatolia Region has the highest lake and river potential in Turkey. Aras, Kura, Tigris, Euphrates and many streams and tributaries feeding these rivers are located in this region. Inland water resources have been declining gradually, especially in recent years, due to the impact of climate change, rapid population growth and pollution. In order to protect these resources, it is necessary to determine the physical, chemical and biological properties of these resources. In addition, it is important to take the restoration measures in cases where regular monitoring of fresh water resources is necessary in terms of the existence of these resources in the future.

Biological diversity can be expressed as the diversity of living communities that are in contact with each other. In other words, biodiversity encompasses all the genes in a region, the species that carry these genes, the ecosystems that host these species, and the events that connect them. In this context, diversity; is a very broad concept that includes the diversity of species, ecosystems and ecological events. Species diversity is the large number of species found in a particular region that includes all species [1, 2].

Among relatively intact streams ecosystems, primary productivity is directly related to flow patterns. Much of the increase in fluvial autotrophy is due to increased production of periphytic algae associated with widespread deposition of sedimentary surfaces and expansion of river folds and folded shallow subsurfaces. When stream ecosystems are disturbed, it increases algal biomass concentrations and potentially significantly increases primary productivity in this region [3].

Species diversity is an important key to our understanding of many systems. The structure and number of periphyton, macrophyte and plankton communities is an important factor in determining the pollution status of rivers. All freshwater algae are sensitive to changes in the water body. Phytoplankton communities are generally found in rivers associated with stagnant bodies of water (dam, lake, etc.) or in slow-flowing parts of rivers crossing large plains. The structure and abundance of phytoplankton communities are affected by the presence of light, temperature and nutrients in lakes, while flow and water velocity affect rivers [4].

The degree of diversity should be specified as a numerical value and diversity indices should be calculated in order to statistically compare the degree of diversity of different systems [5]. Shannon-Wiener, Simpson, Margalef, Menhinick, and McIntosh are the most widely used diversity indeces to obtain information about species richness and distribution of individuals among species at stations [6].

There is constant substance inclusion in streams. For this reason, in addition to being under the influence of the basin through which the stream passes, environmental physical factors can sometimes be more effective than in lentic environments. In streams, where light can enter, there are autochthonous products, algae, algae and higher plants [7]. In order to understand the efficiency of river systems, it is necessary to look at the planktonic richness of the environment and their qualitative and quantitative compositions [8].

Studies have shown that cyanobacteria respond favorably to higher phosphorus concentrations, lower nitrogen-to-phosphorus (N/P) ratios, longer residence time, and less turbulent conditions. In addition, many cyanobacteria can fix nitrogen (converting gaseous nitrogen to ammonia when nitrate is limited), this is expected to provide an advantage for cyanobacteria when nitrogen is limiting. Manier et al. (2021) [9] showed that phytoplankton communities in major rivers tended to transition from cyanobacteria predominant in the upper parts to diatoms predominant in the lower parts. This pattern is likely due to the fact that cyanobacteria lose their competitive advantage (ie access to light) during the turbulent and turbid conditions that prevail in the lower reaches of rivers.

This study focuses on seasonal and temporal variations of the biodiversity and composition of the phytoplankton community in Karasu River, which have not been adequately described yet. It was aimed to contribute to revealing the biodiversity and ecology of this aquatic ecosystem by adding knowledge to the phytoplankton composition and hydrobiology of the Karasu River.

2. Materials and Methods

2.1. Site description

As one of the main tributaries of the Euphrates River, the Karasu River flows from the Dumlu Mountains in the Erzurum Plain and is located in the eastern part of Turkey. It flows through the district of Aşkale and passes through the town of Mercan in the Karasu Valley in the province of Erzincan. It forms the Euphrates River joining the Murat River near the town of Keban. Its length to the Keban Dam Lake is 460 km [10]. This study contains Erzincan Provincial decomposition sections. The convenient stations and coordinates are given in Figure 1.

Figure 1. Location of the Karasu River and the sampling sites

2.2. Sampling and analysis

The phytoplankton samples were collected bimonthly from a depth of 0.5-8 m during the period from January 2019 to July 2019 from five stations. Water samples were taken with a nansen bottle in order to determine the phytoplankton density, species diversity and some water quality parameters at the selected sampling stations. The samples were filtered with 0.45 µm membrane filters and placed in polyethylene bottles.

Physico-chemical parameters including water temperature, pH, condutivity and dissolved oxygen (DO) were measured by a digital multiparameter (Model: YSI Plus) *in situ*.

The chlorophyll-a (630 nm, 645 nm and 665 nm), ammonia-nitrogen (410 nm), nitrite-nitrogen (523 nm), nitrate-nitrogen (410 nm), orthophosphate (720 nm) and total phosphorus (720 nm) were analyzed spectrophotometrically (Model: Beckman Coulter DU730 UV-Vis) [11].

The water samples were first dripped with 10 mLof Lugol's solution in the measuring tapes and kept overnight, then placed in the plankton counting circles (3 mL) and phytoplankton counts were made with the help of an inverted microscope according to the phytoplankton density [12]. Epilytic diatom samples were preserved in Lugol's solution [13]. The diatoms were boiled with equal volumes of nitric acid and sulfuric acid and the water samples were precipitated by dropping Lugol's solution, then fixed preparations were prepared with entellan after removing the acid by washing.

Phytoplankton identification was performed using sedimented water samples or samples taken with plankton scoops according to taxonomic literature [14, 15, 16, 17, 18, 19] under binocular microscope (100x and 400x magnification) [12].

2.3. Biodiversity indices

Four diversity indices (Shannon-Wiener, Simpson, Margalef and Menhinick) were calculated.

2.3.1. Shannon-Wiener diversity index (H')

This index is applied to biological systems which is derived from a mathematical formula by Shannon in 1948 [20]:

$H' = -\sum_{i=1}^{s} pi \log_e pi$, pi=ni/n

Where s is the total number of species and pi is the number of individuals belonging to i species (ni) / total number of individuals (n) [21, 22, 23, 24].

2.3.2. Simpson diversity index (D)

$1\text{-}D = [\sum ni(ni-1)]/N/(N\text{-}1)$

Where ni is the number of individuals belonging to i species and N is the total number of species [21, 22, 23, 24].

2.3.3. Margalef diversity index (D_{mg})

D_{mg}=S-1/LogN

Where S is the number of species and N signifies the number of individuals in a sample [24].

2.3.4. Menhinick diversity index (D_{mn})

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

Where S is the number of species and N signifies the number of individuals in a sample [25, 24].

2.4. Statistical analysis

Seasonal data of ammonia-nitrogen (NH_3-N), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N), total phosphorus (TP), orthophosphate phosphorus (PO_4-P) and chlorophyll-a from sampling stations were analyzed by SPSS 20 using a three-factor Analysis of Variance (ANOVA) in factorial order. DUNCAN test was used to determine the significance level of the difference between groups. The relationship between the diversity indices was examined with the analysis of variance. MINITAB 15 Software was used to interpret the relationship between the indices.

3. Results

Water and plankton samples were taken from 5 stations which were conducted on the part of the Karasu River within the Erzincan Province. Average water temperature, dissolved oxygen, pH and electrical conductivity values were measured as 19.43 °C, 7.9 mg L, 8.3 and 465 mS/cm, respectively.

The variations of the total phosphorus, total orthophosphate, ammonia-nitrogen, nitrite-nitrogen and nitrate-nitrogen values depending on the month and stations were found to be statistically significant ($p<0.05$). Average total phosphorus values in the river according to the stations were calculated as, 1.06±0.04 mg L, 0.47±0.03 mg L, 0.92±0.03 mg L, 0.32±0.02 mg L and 0.68±0.04 mg L, respectively. While the mean orthophosphate value was determined as 0.001±0.0 mg L, the highest value was found in the 2nd station (0.09±0.0 mg L) in January. Ammonia-nitrogen value was found between 1.56±0.0 mg L and 0.66±0.18 mg L throughout the study. The mean nitrite-nitrogen value in the river was determined according to the stations as 0.23±0.0 mg L, 0.20±0.0 mg L , 0.21±0.0 mg L, 0.17± 0.0 mg L and 0.68±0.0 mg L, respectively. The highest value (0.71±0.0 mg L) in the river was detected at 4th station in October, and the lowest value (0.0±0.0 mg L) was detected at 3rd station in the same month. In this study, the mean chlorophyll-a value was calculated as 1.27±0.01 mg L. The lowest value of chlorophyll-a (0.09±0.03 mg L) was detected at the 1st station in January, and the highest value (4.91±0.03 mg L) was detected at the 2nd station in August (Figure 2).

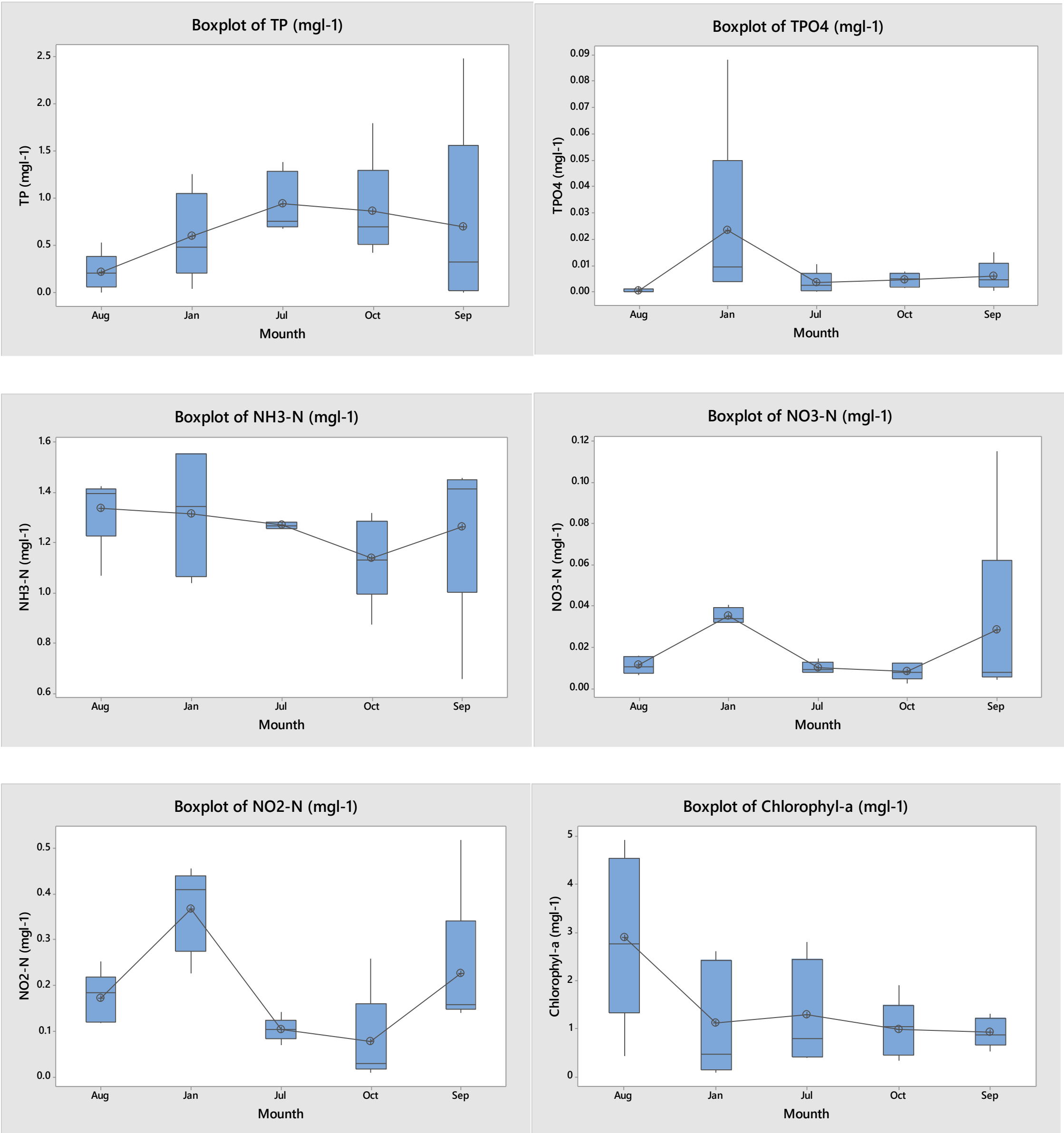

Figure 2. Change of total phosphorus, total orthophosphate, ammonia-nitrogen, nitrate-nitrogen, nitrate-nitrogen and chlorophyll-a values in Karasu River depending on months (n=4)

In this study, a total of 123 phytoplankton species were identified. Among these species, 106 species belonging to Bacillariophyta group, 10 species belonging to Chlorophyta group, 6 species belonging to Cyanobacteria group and 1 species belonging to Euglenophyta group were identified. The availability of the species detected in the Karasu River at the five stations is given in Table 1.

Table 1. Change of phytoplankton species on sampling stations in Karasu River

Species Names	St1	St2	St3	St4	St5
Bacillariophyta					
Cocconeis placentula Ehrenberg 1838	+	+	+	+	+
C.placentula var. euglypta (Ehrenberg) Grunow 1884	+	+	+	+	+
Cymatopleura elliptica (Brébisson) W. Smith 1851	+		+	+	+
Cymbella affinis Kützing 1844	+	+	+	+	+
C.cymbiformis C. Agardh 1830	+	+	+	+	+
C.helvetica Kützing 1844	+	+	+	+	+
C.neoleptoceros Krammer 2002				+	+
Diatoma ehrenbergii Kützing 1844	+	+	+	+	+
D.vulgaris Bory 1824	+	+	+	+	+
Fragilaria capucina Desmazières 1830	+		+	+	+
Gomphonella olivacea (Hornemann) Rabenhorst 1853	+	+	+	+	+
G. augur Ehrenberg 1841		+	+		+
Melosira varians C. Agardh 1827	+	+	+	+	+
Navicula angusta Grunow 1860	+	+	+	+	+
N. bryophila J.B. Petersen 1928	+	+	+	+	+
Nitzschia dissipata (Kützing) Rabenhorst 1860	+	+	+	+	+
N. gracilis Hantzsch 1860	+	+	+	+	+
N. palea (Kützing) W.Smith 1856		+		+	+
Pantocsekiella ocellata (Pantocsek) K.T. Kiss & Ács in Ács & al. 2016:	+		+	+	+
Ulnaria ulna (Nitzsch) Compère 2001	+	+	+	+	+
Chlorophyta					
Acutodesmus raciborskii (Woloszynska) Tsarenko & D.M. John 2011		+			+
Lacunastrum gracillimum (West & G.S. West) H.McManus in McManus & al. 2011			+	+	
Monoraphidium contortum (Thuret) Komárková-Legnerová in Fott 1969				+	+
Pediastrum boryanum var. cornutum (Raciborski) Sulek in Fott 1969	+	+			
P. duplex Meyen 1829		+	+		+
Scenedesmus arcuatus (Lemmermann) Lemmermann 1899	+	+		+	
S. ellipticus Corda 1835			+		
Spirogyra decima var. laxa Kützing 1855		+	+		
Cyanobacteria					
Anabaena flosaquae Brébisson ex Bornet & Flauhault 1886	+			+	
Aphanizomenon gracile Lemmermann 1907					+
Micractinium quadrisetum (Lemmermann) G.M. Smith 1916	+	+			
Microcrocis irregularis (Lagerheim) Geitler 1942	+	+			
M. flosaquae (Wittrock) Kirchner 1898					+
Euglenaphyta					
Euglena acus (O.F. Müller) Ehrenberg, 1830	+				

Throughout the study, Shannon-Wiener, Simpson, Margalef, and Menhinick diversity indexes were calculated as 1.86 H´, 11.53, 5.12 and 0.83 respectively (Table 2.)

Table 2. Shannon-Wiener, Simpson Margalef, and Menhinick diversity indices of the Karasu River

Grups	Count	Sum	Mean	Variance
Shannon-Wiener Diversity Index (H´)	24	46.40	1.86	0.52
Simpson Diversity Index (D)	24	288.20	11.53	26.81
Margalef Diversity Index (D_{mg})	24	128.01	5.12	2.80
Menhinick Diversity Index (D_{mn})	24	20.76	0.83	0.08

ANOVA					
Grups	**SS**	**df**	**MS**	**F**	**P-value**
Shannon-Wiener Diversity Index (H´)	12.38	24	1.39	3.82	0.018
Simpson Diversity Index (D)	643.41	24	88.21	3.86	0.018
Margalef Diversity Index (D_{mg})	67.09	24	6.72	1.68	0.194
Menhinick Diversity Index (D_{mn})	1.99	24	0.30	4.19	0.005

4. Discussion

In this study, some regional physical and chemical parameters of the Karasu River within the Erzincan Province were examined. The changes in total phosphorus, total orthophosphate, ammonia-nitrogen, nitrate-nitrogen and nitrite-nitrogen values depending on months and stations were found to be statistically significant ($p<0.05$). The data on the phosphorus and nitrogen fractions in this study is important as it is the first for the part between the borders of Erzincan Province. In addition, the first data on phytoplankton communities were presented for the same region.

Biodiversity is the qualified dynamic of an ecological system [26]. The distribution of fish and phytoplankton communities in lakes shows spatial and temporal changes. The change in water quality also affects the species diversity of these creatures [27]. For this reason, some living things in aquatic ecosystems are used as bioindicator organisms. The use of bioindicators is very important in evaluating the trophic level of lakes and rivers, as it shows the effects of environmental changes on the living group. In this study, although the number of species in the river is high, species indicating that the river is polluted were identified.

According to the Turkish Environmental Legislation [28], the river is in the I. quality class according to the water temperature and dissolved oxygen values, while it is in the III. class is in the quality class according to pH.

According to the Turkish Environmental Legislation [28], the Karasu River is classified as III. class by total phosphorus value, as class IV by nitrite-nitrogen and class I. by nitrate-nitrogen. This indicates show that there is a high level of organic pollution in the water. Eren and Kaya (2020) [29], in a study investigating the effect of Erzurum Wastewater Treatment Plant on the Karasu River, reported that although the BOD_5 and COD values in the effluent of the treatment plant were low, the BOD_5 and COD values measured in the river increased again, which may be due to agricultural and livestock activities in the surrounding area. Ammonia concentrations in natural waters are generally less than 0.1 mgL. Concentrations higher than 30 mgL can be found in wastewater [30]. In this study, the ammonia-nitrogen value was determined above 1 mgL. This shows that organic pollution is mostly from agricultural activities.

Hilton et al. (2006) [31] reported that there was an increase in the growth of epiphytic and benthic algae in rivers with fast flow, while phytoplankton was dominant in rivers with slow flowing water. In a single sampling study conducted by Gürbüz and Ertuğrul (2003) [32] from the starting note of Karasu River, Bacillariophyta was found to be the most dominant group. *Cyclotella, Fragilaria, Synedra, Melosira, Nitzschia, Diatoma, Cymbelle, Ceratoneis* and *Chlorella* were reported as the most detected species. In this study, Bacillariophyta was determined as the most dominant group, while *Cocconeis placentula var. euglypta*, *Pantocsekiella ocellata* and *Craticula subminuscula* were the most detected species.

In the study carried out in the Karasu River, where the nutrients are not limiting and alkaline water features, it was reported that the *Cyclotella meneghiniana* was the dominant species [33]. In this study, the dominant species is *Cocconeis placentula*.

During this study, the lowest value of chlorophyll-a (0.09±0.03 mg L) was calculated at the 1^{st} station in January, and the highest value (4.91±0.03 mg L) was calculated at the 2^{nd} station in August. In the Melen River the chlorophyll-a value ranged between 0.009 and 0.64 mg L, and the phytoplankton abundance and biomass were low in winter months and high in late spring summer months like our study. It has been reported that the relationship between phytoplankton abundance, chlorophyll-a and temperature is important [34].

Based on the three diversity indices, the water quality was classified into four grades: no pollution ($D_{mg} > 5.0$ and $H' > 3.0$), light pollution ($5.0 > D_{mg} > 4.0$ and $3.0 > H' > 2.0$), moderate pollution ($4.0 > D_{mg} > 3.0$ and $2.0 > H' > 1.0$), and heavy pollution ($3.0 > D_{mg} > 0.0$ and $1.0 > H' > 0.0$) [35, 36]. While the Karasu River is determined as heavily polluted according to the Shannon-Weaver index, it is in the non-polluted area class according to the Margalef index. The classification of the river according to the Margalef index is in accordance with the classification of the Turkish Environmental Legislation [28] according to the water temperature, dissolved oxygen and nitrate-nitrogen value. The classification of the river according to the Shannon-Weaver index is also compatible with the classification according to the pH, total phosphorus and nitrite-nitrogen values according to the Turkish Environmental Legislation [28].

Ding et al. (2021) [37] stated that the water quality parameters such as sediment and nutrient load significantly affect phytoplankton diversity patterns in Yellow River. Hovewer, Geo-climatic factors, such as water surface slope and annual mean precipitation and temperature, also provided non-negligible contributions to the variation in phytoplankton diversity indices. Therefore, in river ecosystems with a large geographical span and complex topography, phytoplankton diversity is not a suitable water quality indicator, although it can reflect habitat changes to a certain extent.

5. Conclusion

In the present study, the indece-based assessment of the Karasu River was differed. For this reason, the view that it requires the determination of the reference conditions used to control the extent of the change in wide-spread rivers and that all these processes need to be done in a large number of water bodies [38] is supported. As a result of this study, phytoplankton diversity indices is not a suitable water quality indicator. However, introducing reference conditions for different cities can increase the usability of the indices. For this reason, we recommend that these studies continue and expand. Furthermore, the presence of Cyanobacteria in natural environments is an important indicator of pollution, so it is recommended to monitor these systems regularly. Further study may be required to species richness as well as density of harmful species for evaluating the ecological quality status of the region.

Ethics in Publishing

There are no ethical issues regarding the publication of this study

Author Contributions

Özden FAKIOĞLU: Designing the study, analysis of water parameters, evaluation of results, statictical calculations, writing the article

Özge ZENCİR TANIR: Designing the study, evaluation of results, writing the article

Zeliha AKYÜZ: Analysis of water parameters, statictical calculations, writing the article

Muhammet Furkan TOPAL: Analysis of water parameters, statictical calculations, writing the article

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References

[1] Erten, S. (2004) Biodiversity as a rising value at the international level. Hacettepe University Faculty of Education Journal, 27:1-10.

[2] Gülsoy, S., Özkan, K. (2008) Ecological importance of species diversity and some used indices. Süleyman Demirel University Faculty of Forestry Journal, Ser. A(1), 168-178.

[3] Wetzel, R.G. (2001) Limnology,.W.B. Saunders Company, No. DOE/EV/01599-235-Pt. 4; COO-1599-235-Pt. 4; COO-1599-234). Michigan State Univ., Hickory Corners (USA). WK Kellogg Biological Station London.

[4] Allan, J.D. (1995) Stream ecology. The Netherlands: Kluwer Academic Publishers.

[5] Odum, E.P., Barrett, G.W. (2005) Basic principles of ecology. In: Işık K, translation editor. Ankara: Palme Publishing, 598 (in Turkish)

[6] Jorgensen, S.E., Costanse, R., Xu, F.-L. (2005) Handbook of ecological indicators for assessment of ecosystem health. London, Taylor and Francis Group Eddition.

[7] Tanyolaç, J. (2000) Limnology (Freshwater Science). Cumhuriyet University, Faculty of Arts and Sciences, Department of Biology, Hatipoğlu Publishing House, Ankara (in Turkish)

[8] Sönmez, A.Y., Hisar, O., Karataş, M., Arslan, G., Aras, M.S. (2008) Waters Information. Nobel Publication No: 1258, Science: 64, 1st Edition.

[9] Manier, J.T., Haro, R.J., Houser, J.N., Strauss, E.A. (2021) Spatial and temporal dynamics of phytoplankton assemblages in the upper Mississippi River. River Research and Applications, 37(10), 1451-1462.

[10] Saler, S., Bulut, H., Birici, N., Tepe, R., Alpaslan, K. (2015) Zooplankton of the Karasu River (Erzincan). Egirdir Faculty of Fisheries Journal, 11(1), 10-16.

[11] Anonymous, (1995) Standard methods for the examination of water and wastewater. Washington: American Public Health Association (APHA).

[12] Utermöhl, H. (1958) Zur Vervolkommnung deer quantitativen phytoplankton-methodik, Mitteilungen der Internationale Vereinigung der theoretretische und Angewandte. Limnologie, 5; 567-596.

[13] Round, F.D. (1953) An Investigation of two benthic algal communities in Malham Tarn. Yorkshire. J. Ecol., 41; 174-197.

[14] Cox, E.J. (1996) Identification of freshwater diatoms from live material. London: Chapman and Hall.

[15] Hustedt, F. (1930) Bacillariophyta (Diatomeae), Heft 10. In: A. Pascher (Ed), Die Süsswasser –Flora Mitteleuropas, Verlag von Gustav Fisher, Jena, 466 p, Stuttgart.

[16] Huber-Pestalozzi, G. (1942) Das Phytoplankton des Süsswassers, 2 Teil. Diatomeen. In: A. Thıenemann (Ed), Die Binnengewasser, E. Schweizerbart'sche Verlagsbuchhandlung, 549 p., Stuttgart.

[17] Huber-Pestalozzi, G. (1950) Das Phytoplankton des Süsswassers, 3 Teil. Cryoptophyceen, Chloromonadien, Peridineen. In: A. Thienemann (Ed), Die Binnengewasser, E. Schweizerbart'sche Verlagsbuchhandlung, 310 p., Stuttgart

[18] John, P.M., Whitton, B.A., Brook, A.J. (2002) The freshwater algal flora of the British Isles. Cambridge Univ. Press, Cambridge.

[19] Lind, M.E., Brook, A.J. (1980) A key to the commoner desmids of the English Lake district. Freswater Biol. Assoc. Publ., 123, Cumbria.

[20] Türkmen, G., Kazancı, N. (2010) Applications of various biodiversity indices to benthic macroinvertebrate assemblages in streams of a national park in Turkey. Review of Hydrobiology, 111-125.

[21] Hill, M.O. (1973) Diversity ve evenness: a unifying notation and its consequences. Ecology, 427-432.

[22] Krebs. C.J. (1998) Ecological methodology. 2nd edition. Benjamin/Cummings, Menlo Park, California.

[23] Kwak, T.J., Peterson, J.T. (2007) Community indices, parameters, and comparisons. in C.S. Guy and M.L. Brown, Editors. 677-763. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland. ISBN-13: 978-1-888569-77-3.

[24] James, B.K., Adejare, L.I. (2010) Nutrients and phytoplankton production dynamics of a tropical harbor in relation to water quality indices, J. Am. Sci, 261-275.

[25] Menhinick, E.F. (1964) A Comparison of some species-individuals diversity indices applied to samples of field insects, Ecology, 859-861.

[26] Cetinkaya, O. (2006) Exotic and native fish species inoculated or stocked in Turkish waters, their effects on aquaculture, fisheries, natural populations and aquatic ecosystems: a preliminary study for a database. I. Fishing and reservoir management symposium, 7-9 February (205-235), Antalya. (in Turkish).

[27] Bobori, D.C., Salvarina, I. (2010) Seasonal variation of fish abundance and biomass in gillnet catches of an East Mediterranean lake: Lake Doirani. Journal of Environmental Biology, 31, 995-1000.

[28] Anonymous, (2012). Water quality criteria according to classes of inland water resources according to Turkish Environmental Legislation, Regulation on Surface Water Quality Management. Part One. Ministry of Forestry and Water Management. Issue: 28483 Official Gazette. 26s. (in Turkish).

[29] Eren, Z., Kaya, F. (2020) Biodiversity as a rising value at the international level. Hacet Uni. Education Faculty Journal, 27, 1-10. (in Turkish).

[30] Anonymous, (2004). Water Pollution Control Regulation. Ministry of Environment and Forestry. 1-55. Ankara (in Turkish)

[31] Hilton, J. O'Hare M., Bowes, M.J., Jones, J.I. (2006) How green is my river: a new paradigm in eutrophication in rivers. Sci. Total Environ, 365, 66-83.

[32] Gurbuz, H., Ertugrul, M. (2003) Determination of medium elements in algae of Karasu (Fırat) River by EDXRF using an 241Am excitation source. Instrumentation Science & Technology, 31(2), 189-196.

[33] Gürbüz, H. (1990) A Research on the algae flora of the Karasu (Euphrates) River, Atatürk University Institute of Science and Technology (Unpublished Master's Thesis dissertation), 82.

[34] Baykal, T., Açıkgöz, İ., Udoh, A.U., Yıldız, K. (2011) Seasonal variations in phytoplankton composition and biomass in a small lowland river – lake system (Melen River, Turkey). Turk J. Biol., 35, 485-501.

[35] Margalef, R. (1958) Information theory in biology. General Systems Yearbook, 3, 36-71.

[36] Shannon, C.E. (1948) A mathematical theory of communication. The Bell system technical journal, 27(3), 379-423.

[37] Ding, Y., Pan, B., Zhao, G., Sun, C., Han, X., Li, M. (2021) Geo-climatic factors weaken the effectiveness of phytoplankton diversity as a water quality indicator in a large sediment-laden river, Science of The Total Environment, 792, 148346.

[38] Cetin, T. (2014) Biological quality elements according to the water framework directive: phytoplankton and phytobenthos. Unpublished expertise dissertation, T.C. Ministry of Forestry and Water Affairs, 144. Ankara. (in Turkish)