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Research Article

Water Quality Assessment of Derinçay Stream (Çorum) by Biotic Indices

Süleyman İpek[1], Faruk Maraşlıoğlu[2]

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ABSTRACT

In this study, counting and identification were performed on epiphytic diatom samples taken from 6 sampling stations located on the Derinçay Stream (Çorum). In the study, 42 taxa belonging to Bacillariophyta were identified, and the dominant taxon of the stream was *Nitschia palea*. According to some biotic indices such as the Trophic Diatom Index (TDI) and Saprobic Index (SI), it was determined that the Derinçay Stream has a hypertrophic trophic structure corresponding to the "bad" ecological status with an average TDI value of 79.8, and according to the SI, the upper stations (St1, St2) were organically slightly polluted corresponding to β-mesosaprobic, while the other stations were determined to be heavily polluted corresponding to α-mesosaprobic. When looking at the similarities of the stations, the stations with the highest similarity values were the 4th and 6th stations, while the similarity of the 1st and 6th stations was low. When Shannon diversity index (H’) averages are examined, the stream is classified as "low diversity" and "heavily polluted". According to the Pielou evenness index (J’), the community balance at the epiphytic flora stations was better in other months, except February 2021. According to Margalef's species richness index (d), species richness decreases upstream from downstream. When the data in the study area are evaluated, it was seen that the stream is under the threat of pollution, and the SI results represented the ecological structure of the stream better than the TDI results.

Keywords: Diatom, Stream, Biotic Index, Water Quality

ORCID IDs of the author:
S.İ. 0000-0003-3176-4751;
F.M. 0000-0002-7784-9243

[1]Department of Biology, Graduate School, Hitit University, Çorum, Türkiye

[2]Department of Molecular Biology and Genetics, Faculty of Arts and Science, Hitit University, Çorum, Türkiye

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Correspondence:
Süleyman İpek
E-mail:
suleimanipek@gmail.com

INTRODUCTION

Despite the positive effects of developing technology and industrialisation that make human life easier, their negative effects on the environment cannot be ignored (Sun et al., 2019). Changes in consumption habits due to technological developments, waste of natural resources, rapid population growth, irregular urbanisation due to irregular migration and damage caused by industrial establishments lead to the deterioration of the ecological balance and cause irreparable consequences (Karagözoğlu, 2020). Pollutants from point or nonpoint sources originating from agricultural, urban, and/or industrial activities, particularly in lower river basins, negatively impact water quality and alter the structure of algal communities in aquatic ecosystems. Spatial and temporal variations in algal communities are excellent indicators of environmental changes, as algae offer comprehensive and descriptive insights into water quality by immediately reflecting physicochemical parameters (Taş et al., 2019). Water resources are classified into physicochemical and biological classes. Therefore, biological approaches must be used to support chemical assessments (Çiçek & Ertan, 2015). The number of studies on the biological classification of water quality has increased with the publication of the EU Water Framework Directive (WFD, 2000/60/EC), and various studies abroad have suggested that the trophic status of updated diatoms can be used as an indicator of water quality (Eassa et al., 2015; Liu et al., 2020). In parallel with studies in Europe, monitoring of the ecological status of determining water quality biologically has also increased over time in our country (Kalyoncu et al., 2009; Gürbüz & Kıvrak, 2002; Solak, 2011; Maraşlıoğlu et al., 2020; Sevindik et al., 2023).

In recent years, after the establishment of relationships between diatoms and environmental factors, the number of studies on determining river water quality using diatoms has significantly increased (Richards et al., 2020; Masouras et al., 2021; Dalu et al., 2022). Many diatom indices have been developed in various countries worldwide, especially in Europe, to assess the water quality and pollution status of rivers. Some of these indices include the following: CEE (CEC): Descy and Coste Diatom Index (Descy & Coste, 1991); GDI: Generic Diatom Index (Coste & Ayphassorrho, 1991); SHE: Steinberg and Schiefele Index (Steinberg & Schiefele, 1988); and TDI: Trophic Diatom Index (Kelly & Whitton, 1995; Kelly, 1998).

The first study on the biological assessment of river water quality in Turkey were conducted by Girgin and Kazancı (1994). In this study, Girgin and Kazancı (1994) evaluated the water quality of the Ankara Stream not only based on physicochemical parameters but also using biological indices of benthic macroinvertebrates. The use of diatom indices for assessing water quality in rivers in our country has been recently reported, and the number of studies is quite limited. Barlas et al. (2001) assessed the water quality of Sarıçay and Akçapınar Stream using epilithic diatoms according to the Sládeček Index (SLA) index. Gürbüz and Kıvrak (2002) evaluated the water quality of the Karasu River based on epilithic diatoms using the Generic Index (GI), Trophic Diatom Index (TDI), Sládeček Index (SLA), and Diatom Association Index for Organic Pollution (DAIpo). The water quality of streams and rivers around Isparta (Isparta, Aksu, Darören) was assessed based on physicochemical data and diatom indices, including the Swiss Diatom Index (DI-CH), Trophic Index (TI), and Saprobic Index (SI) (Kalyoncu & Barlas, 1997; Kalyoncu et al., 2009). The water quality of streams and rivers in western Turkey was evaluated based on physicochemical data and diatom indices using Omnidia software (Solak, 2011).

The aim of this study was to determine the water quality of the Derinçay Stream both in terms of physicochemical and biological aspects, identify pollution sources along the river and their impacts on the system, evaluate the stream water, and obtain some findings that could be useful in taking measures to maintain balance in the system. For this purpose, the relationship between the benthic diatom community and the water quality of the Derinçay stream was examined, and the stream water quality was assessed using the Saprobic Index (SI) and the trophic diatom index (TDI). Additionally, the relationship between the diatom indices and the physicochemical properties of stream water was investigated.

MATERIAL AND METODS

Study sites and sampling points

The stations were selected so that they could both provide access to the stream and offer representative samples of water quality along the stream length. For this purpose, six stations were selected before and after evaluating various businesses and facilities on Derinçay Stream (Fig. 1). The stream was classified into three sections: upstream, stations from St1 to St2, midstream, stations from St3 to St4, and downstream, stations from St5 to St6. The first (St1) and second (St2) stations are connected to an agricultural area, while St2 is also associated with industrial and livestock activities. The third station (St3), which is within the vicinity of intensive industrial settlements and urban areas, was selected from the stream midstream reaches. It should be mentioned that the third station (St3) was affected mainly by farming, large factories, and industrial zones. Most of the waste from these facilities is discharged into the stream without any treatment during the study period. The Urban Wastewater Treatment Plant of Çorum located in Karacaköy fed the fourth sampling point (St4) with wastewater. The fifth station (St5) was chosen near the Sarılık village and is located after the discharge point of the Çorum Sugar Factory. Finally, the St6 sampling site, which had no specific industrial activity, was at a point after the Alaca Creek flows into the Derinçay Stream.

Samplings and analyses

Samples of equal amounts each time were collected monthly from the stems and leaves of *Cladophora glomerata* at stations 1, 2, and 5, *Phragmites australis* at stations 3 and 4, and *Typha latifolia* at station 6 to examine epiphytic algae in the Derinçay Stream. Phytobenthos sampling was conducted using standard methods. Because there were not many stone samples found at the river stations during phytobenthos sampling, the epiphytic algae community distributed on the plant surfaces varied according to the stations. The collected plant samples were washed with distilled water and scraped to collect the organisms living on them into containers. After being brought to the laboratory, the samples were transferred to measuring cups and sedimentation was performed. The sedimented parts of the samples were

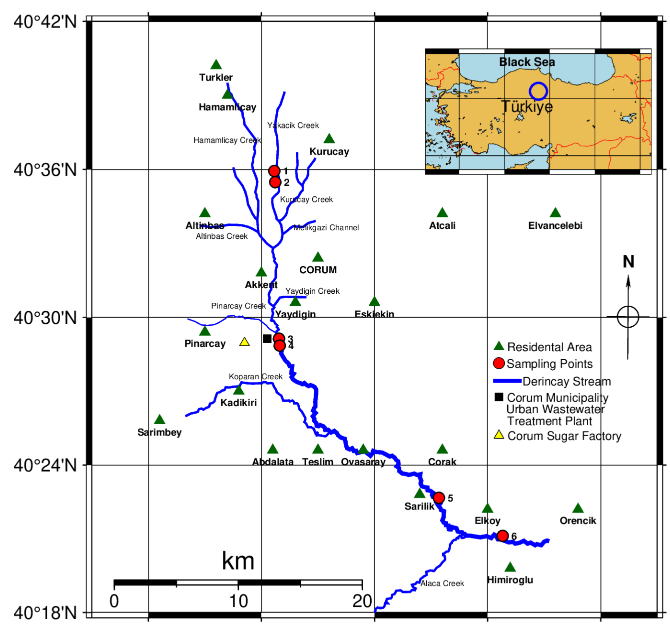

Figure 1. Water quality monitoring stations in the Derinçay Stream (Wessel et al,. 2019).

transferred to centrifuge tubes, and successive treatments with HCl, centrifugation, treatment with H_2O_2 in a hot water bath, and centrifugation were performed (Swift, 1967). Thus, diatom species with only siliceous cell walls (valves) were recovered from organic matter, and permanent preparations were made with "Entellan" mounting medium (Hasle, 1978). Preparations were examined using an Olympus BX51 research microscope at 400x magnification. In each examined preparation, 400 diatom valves (frustules) were counted, and taxa were identified. Krammer and Lange-Bertalot (1991a, 1991b, 1999a, 1999b), Round et al. (1990), and Hartley et al. (1996) were used to diagnose diatoms.

The temperature, pH, electrical conductivity, and dissolved oxygen concentration of the stream water were measured at the time of sampling using a portable YSI Proplus multiparameter measurement device. The measurements of biochemical oxygen demand (BOD5), chemical oxygen demand (COD), orthophosphate (PO_4-P), total nitrogen (TN), total phosphorus (TP), ammonium nitrogen (NH_4-N), and nitrate nitrogen (NO_3-N) concentrations were conducted through service procurement at Çorum Food Control Laboratories according to the standard methods recommended by APHA (2005).

Trophic and Organic Pollution Indices

The first version of the TDI was empirically derived from graphs summarising the percentage of occurrence against dissolved phosphorus concentrations for 86 taxa (genera and key indicator species: Kelly & Whitton, 1995). This value ranged from 1 (low nutrient concentration) to 5 (very high nutrient concentration). However, the research staff later expressed a clear preference for an index that produces integer values over a wider numerical range. Therefore, the TDI was modified to extend from 0 (low nutrient concentrations) to 100 (very high nutrient concentrations) (Table 1). These calculations were performed using the following equations.

TDI = (WMS x 25)- 25

TDI stands for Trophic Diatom Index, and WMS is calculated as weighted wean sensitivity.

$$\text{WMS} = \Sigma\, ai \times si \times vi \,/\, \Sigma\, ai \times vi$$

where ai represents the abundance of species *i* in the sample, *si* represents the sensitivity of species *i* to pollution (1-5), and *vi* represents the indicator value (1-3).

The organic pollution level at each station was calculated using the saprobic index formula proposed by Pantle and Buck (1955). The saprobic index (SI) was calculated using the following formula: the sum of saprobic values for all identified indicator species divided by the sum of frequency values for all indicator species.

$$S = \Sigma\, si \times hi \,/\, \Sigma\, ai$$

S is the saprobic index of the algal community; *si* represents the ecological indicator value of freshwater diatoms (Van Dam et al. (1994) for each species; *hi* represents the frequency value of species *i* (three-scored; rare = 1, common = 3, abundant = 5), *and ai represents the abundance* of species *i*.

Diversity and Evenness Indices

Diversity, evenness, and species richness indices are commonly used to determine species diversity and distribution in aquatic ecosystems. For each month at the specified stations in Derinçay, species counts and individual counts of each species were determined. Using the obtained data, the Shannon diversity index (H'), Pielou evenness index (J'), and Margalef species richness index (d) were calculated using the Primer software package programme (Clarke & Ainsworth, 1993). Additionally, to describe a community in terms of diversity and similarity and to compare it with another community, it is necessary to count the species and individuals belonging to the community one by one in the community. For this purpose, the degree of similarity among the sampling stations was calculated using the Sorensen similarity index (Kocataş, 1994).

RESULTS AND DISCUSSION

Physical and chemical variables

The water quality parameters affecting the periphyton community, including temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium (NH_4^+), nitrate (NO_3^-), orthophosphate (o-PO_4), total nitrogen (TN), and total phosphate (TP), are presented in Table 3. The values of some physical variables (temperature, pH) were at a good quality standard for periphyton growth, but the other parameters had values that exceeded the quality standard at certain seasons. Levels of oxygenation and nutrient parameters in stations that exceed the quality standard are attributed to agricultural activities, domestic waste and industrial waste around the location. However, in the Brantas River (Indonesia), ammonia and total organic matter exceeded accepted levels, but other water quality parameters were within surface water quality standards (Arsad et al., 2021).Water quality parameters showed significant spatial variations, increasing at St4 and St5 and then slowly decreasing with the contribution of Alaca Creek at St6 (Table 3). Regarding water quality classifica-

Table 1. TDI-Trophic Diatom Index scale (Kelly & Whitton, 1995).

Index Range (0–100)	Water Quality Class	Ecological Status	Trophic Status
< 35	I	Very Good	Oligotrophic
35 - 50	II	Good	Oligo- Mesotrophic
50 - 60	III	Moderate	Mesotrophic
60 - 75	IV	Poor/Low	Eutrophic
> 75	V	Bad	Hypertrophic

tion, the physical variables (temperature, pH, EC) in the stream showed no significant spatial variations, whereas there were notable temporal and spatial variations in DO, BOD, COD, NH_4^+, NO_3^-, TN, TP, and o-PO_4 environmental variables. Among the in situ measurements, water temperature showed similar seasonal patterns along the stream length, except upstream, with a slightly prolonged winter cold period. During the study conducted in Derinçay Stream, the lowest water temperature was measured at 3.7°C at the 1st station in November 2020, while the highest temperature was recorded at 23.4°C at the 4th station in August 2020. It was observed that the annual variation in water temperature in the Derinçay Stream follows seasonal averages. According to the Surface Water Quality Regulation (2021), Derinçay Stream has Class I water quality in terms of average water temperature. The average pH values measured at the Derinçay stream stations were 8.22, 7.97, 8.02, 8.03, 8.06, and 8.11, respectively, indicating that the river has slightly alkaline properties. It is known that some diatoms such as *Fragilaria*, *Nitzschia*, and *Cyclotella* prefer slightly alkaline waters (Reynolds, 1993), and these genera have been frequently encountered in our study area as well. Additionally, according to the Surface Water Quality Regulation (2021), Derinçay Stream has Class I water quality in terms of average pH values. The opposite relationship was observed for EC, which decreased upstream (1145 µS/cm) and increased midstream (1427 µS/cm). The conductivity of water is directly related to its salinity, density, and ion concentration (Cirik & Cirik, 2005). In the study area, the average electrical conductivity value was measured as 1277 µS/cm. This indicates that the water quality is low, and Derinçay Stream has Class III water quality in terms of average conductivity according to Surface Water Quality Regulation (SWQR, 2021). The dissolved oxygen value is crucial for aquatic organisms (Çıtakoğlu & Özeren, 2021). DO showed increasing values both upstream and seasonally in cold months, with a maximum value of 6–8 mg/L, while the lowest values were recorded in autumn months. According to the classification of dissolved oxygen values by SWQR (2021), St1 had Class II water quality, while the other stations in the Derinçay Stream had Class III water quality. The biological oxygen demand (BOD) is considered a measure of organic pollution in water environments (Atay & Pulatsü, 2000). The BOD and COD values were reduced at St1 and St2, which corresponded to the upstream (6 mg/L and 16.1 mg/L, respectively) and reached their highest values at St4, which corresponded to the after wastewater treatment (110 mg/L and 117 mg/L, respectively). According to SWQR (2021), in terms of BOD values, the 1st station has Class I, the 3rd station has Class II, and the other stations (St2, St4, St5, St6) have Class III water quality. The chemical oxygen demand (COD) had the lowest value at the 1st station (8.91 mg/L) and the highest value at the 4th station (117 mg/L. According to the SWQR (2021), stations 1, 2, and 3 have Class I water quality, and stations 4, 5, and 6 have Class III water quality in terms of COD. Nutrients (TP, TN, NO_3^- and NH_4^+) reached their highest concentrations at St5 and lowest concentrations at St2. Based on SWQR (2021), the water quality of the Derinçay Stream for ammonium and nitrate is classified as Class I at St1 and St2, Class II at St3 and St4, and Class III at St5 and St6. In terms of total nitrogen (TN) values, St1 and St2 have

Table 2. Saprobic index (Pantle & Buck, 1955).

Index Range (1–4)	Water Quality Class	Ecological Status	Sabrobity
1 - 1.5	I, I-II	Clean	Oligosaprobity
1.5 - 2.5	II	Moderately polluted	β-mesosaprobity
2.5 - 3.5	III-IV	Heavily polluted	α-mesosaprobity
3.5 - 4	IV	Excessively polluted	Polysaprobity

Table 3. Mean values of physicochemical parameters according to station.

Parameters	St1	St2	St3	St4	St5	St6
General parameters						
Temperature (ºC)	11,6	11,7	14,1	17,3	14,7	13,9
pH	8,22	7,97	8,02	8,03	8,06	8,11
EC (µS/cm)	1120	1169	1449	1404	1356	1085
Oxygenation parameters						
DO (mg/L)	6,0	5,3	3,3	1,9	3,4	3,7
BOD (mg/L)	1	11	6	110	32	21
COD (mg/L)	8,9	23,3	15,6	117	55,7	54
Nutrient Parameters						
NH_4^+ (mg/L)	0,1	0,2	0,63	0,69	16,4	9,95
NO_3^- (mg/L)	2,6	1,6	4,2	7,3	21,4	13,6
TN (mg/L)	2,8	1,9	4,9	12,6	17,2	9,85
TP (mg/L)	0,1	0,4	2,8	3,5	3,9	2,4
o-PO_4 (mg/L)	0,2	1,25	8,7	10,5	11,3	7,2

Class I water quality, St3 and St6 have Class II, and St4 and St5 have Class III water quality according to SWQR (2021). Regarding total phosphorus (TP) values, St1 had Class II water quality, while the other stations had Class III water quality according to the SWQR (2021). The orthophosphate concentration started to increase at St4 and peaked at St5 (11.3 mg/L). In the following section of the stream, the trend is decreasing. A similar classification TP was observed for the orthophosphate values, where the stream was classified as Class III for all stations, indicating poor water quality.

Distribution of Epiphytic Diatoms

The dominant epiphyton species in the Derinçay Stream were observed to be the same in the middle and lower sections of the stream. The relatively less polluted St1 was characterised by *Fragilaria tenera* and the partially polluted St2 was characterised by *Ulnaria ulna*. On the other hand, the highly polluted mid-stream and downstream sites (St3, St4, St5 and St6) were characterised by *Nitzschia palea*. Bere and Tundisi (2011) reported a similar result for the Monjolinho River. However, a study on the temporal and spatial distribution of epiphytes in the Diyala River identified some epiphytic species, including *Gomphonema parvulum*, *Ulnaria acus*, *Cyclotella meneghiniana*, *Navicula gregaria*, and *Nitzschia amphibia*, as bioindicator species of pollution (Hassan et al., 2023). The subdominant species at the stations were as follows: *Navicula phyllepta* and *Ulnaria ulna* at St1, *Rhoicosphenia abbreviata*, *Navicula cryptotenella*, and *Diatoma moniliformis* at station 2, Navicula veneta and Navicula lanceolata at station 3, *Navicula veneta* and *Rhoicosphenia abbreviata* at St4, *Nitzschia littoralis* at St5, and *Craticula cuspidata* at St6. In the entire study area, *Nitzschia palea* and *Fragilaria tenera* were the dominant species, while *Navicula veneta* and *Ulnaria ulna* were the subdominant species. Dominant and subdominant taxa comprised 53% of the epiphytic community in the study area.

Diatome indices

According to the Trophic Diatom Index calculated using epiphytic diatoms identified in Derinçay, the lowest average TDI value was 55.3 at St1. The highest average TDI value was determined to be 93.7 at St6. When we examined the monthly TDI values of the six sampling stations; at St1, the highest TDI value was determined to be 81.6 in October 2020, and the lowest was 31.5 in February 2021. The annual TDI at St1 was 55.3. At St2, the highest and lowest values were 91.7 and 66.7, respectively, indicating generally eutrophic water quality. The annual TDI at St2 was 72.3. The annual TDI at St3 was calculated as 81.3, with the highest monthly TDI value of 87.5 in October 2020 and the lowest TDI value of 65.6 in July 2021. The TDI at St4 was determined to be 86.7. The highest TDI value was 97.5 in November 2020, and the lowest TDI value was 58.3 in October 2020. The TDI value at St5 was determined to be 89.7, with the highest monthly TDI value of 98.6 in July 2021 and the lowest value of 75 in June 2021. St6 had the highest annual TDI of 93.7, with the highest monthly TDI of 100 in April 2021 and the lowest of 37.5 in December 2020 (Table 4).

Low TDI values indicate low nutrient levels, while high index values indicate eutrophic conditions in the water (Kelly, 1998). Accordingly, Derinçay Stream has an average TDI value of 79.8, indicating a hypertrophic trophic structure corresponding to the "poor" water quality class. According to the TDI results determined based on the epiphytic flora in phytobenthos, except for station 1 (moderate water quality), the water quality conditions at other stations are "poor" or "bad". Solak (2011) stated in a study conducted in the Upper Basin of the Porsuk River that, similar to Derinçay, areas close to the source were of Class II (oligo-mesotrophic) water quality, while the region near the Kütahya exit was of Class V (hypertrophic) water quality based on TDI values. When we examined the TDI results of the Derinçay Stream seasonally, although there was partial improvement in water quality in the winter season (weak ecological structure), we generally observed that the water quality is "poor" in all four seasons. In February 2021, there was a sudden increase in the number of organisms of *Fragilaria tenera* species with low pollution sensitivity (S: 2) at station 1, contributing to the partial improvement in water quality during the winter season. In the spring, which is the season when water quality is worst, increases in the numbers of species with high pollution sensitivity (S: 4/5), such as *Nitzschia palea*, *Navicula lanceolata*, and *N. veneta*, have contributed to the decrease in water quality. Despite the low number of organisms recorded in phytobenthos, especially in the summer and spring months, the fact that the existing species have high pollution sensitivity indicates that the ecological structure of the area is in very poor condition. The situation where TDI values calculated based on the low number of diatoms in the phytobenthos flo-

Table 4. Seasonal variation of the Trophic Diatom Index by sampling station.

TDI	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20	Jan 21	Feb 21	Mar 21	Apr 21	May 21	Jun 21	Jul 21	Mean
St1	*	79,3	81,6	61,5	54,9	45,8	31,5	69,1	59,2	*	*	*	55,3
St2	*	*	*	85,7	66,7	91,7	70,8	69,1	75	*	*	*	72,3
St3	70	68,8	87,5	75	70,9	75,7	73,8	82,2	84,9	83,6	84,5	65,6	81,3
St4	91,7	93,8	58,3	97,5	90	85	78,3	92,9	92,5	81,7	77,8	91,7	86,7
St5	87,5	87,5	81	93,8	90	90	89	83,5	94,5	86,5	75	98,6	89,7
St6	65,8	81,3	58,5	71,5	37,5	88,5	98	88,8	100	83,5	75	80	93,7

*Water shortage

ra do not fully reflect the actual water quality level and trophic structure of the environment was also reported by Temizel (2022) in a study on benthic algae in the Harşit Stream.

According to the Saprobic Index (SI), stations 1 and 2 represented Class II water quality (slightly polluted), while stations 3, 4, 5, and 6 represented Class III-IV water quality (heavily polluted). When the SI results are analysed seasonally, it was observed that at St1, except for August, samples taken during the autumn, winter, and spring seasons were characterised by β-mesosaprobic (moderately polluted) conditions. In contrast, α-mesosaprobic (heavily polluted) conditions mostly characterized the samples taken during the winter and spring seasons at St2. At St3 (in the middle part of the stream, except for August and September, α-mesosaprobic (heavily polluted) conditions were dominant in all months. At St4, although there were fluctuations in the saprobic index values on a monthly basis, rises and falls were observed in September, December, and July (polysaprobic), while decreases were observed in October and June (β-mesosaprobic). However, the overall dominant condition was α-mesosaprobic (heavily polluted), as seen in most stations. A similar situation was observed at St5, where polysaprobic (extremely polluted) conditions prevailed in August, September, December, April, and July, while α-mesosaprobic (heavily polluted) conditions dominated the other months of the year. At St6, fluctuations in the sabrobic index values on a monthly basis were also observed, with increases in September and April (polysaprobic) and decreases in August, October, and March (β-mesosaprobic). However, the general dominant condition at this station, as with most stations, was α-mesosaprobic (heavily polluted) (Table 5).

It was observed that the SI results calculated using epiphytic diatoms at the stations of the Derinçay Stream better represented the ecological structure of the stream than the TDI results. However, in a study conducted by Kalyoncu et al. (2009) to determine the water quality of Aksu Stream based on biological indices, it was reported that the SI index better reflects pollution than the TDI index. Solak (2011) reported that water quality categories determined based on diatom indices vary between stations, which could be due to differences in diatom communities used in each index. Although the water quality classes determined based on physicochemical analysis corresponded to the diatom indices at some stations, deviations were observed at other stations. The water quality grade determined by the Saprobic Index showed a half-step positive deviation from the water quality classes determined by Klee (1991) at all stations. Within the scope of the Trophic Diatom Index, the water quality classes at stations 1, 2, 3, and 4 perfectly matched the water quality steps determined by Klee (1991), whereas stations 5 and 6 showed a half-step negative deviation. It has been noted by various researchers (Kalyoncu et al., 2009; Gómez & Licursi, 2001) that discrepancies can occur between water quality steps determined by physicochemical analysis and those determined by biological analysis.

Statistical analysis

Similarities between epiphytic algae

According to the similarity analysis results of epiphytic algae at the sampling stations of Derinçay Stream, the highest value (0.75) was observed between stations 4 and 6, whereas the lowest value (0.31) was observed between stations 1 and 6. It was found that high values in the similarity analysis of epiphytic algae at the sampling stations do not reflect the reality very well, but there are significant differences in organism numbers and species diversity between stations where similarity is reflected as low (Table 6).

Diversity and evenness of epiphytic algae

Diversity index measurements can be used to indicate the status of the ecological system and habitat characteristics. Diversity depends on the ecological roles of competition, predation, and succession (Valiente-Banuet et al., 2015). Diversity is defined as the number of different individuals in an ecosystem relative to the total number of all individuals in the ecosystem (Herawati et al., 2019). Changes in the diversity index reflect the effects of environmental changes on aquatic ecosystems (Ye et al., 2017).

Throughout the study period, the station with the richest species diversity according to the Shannon diversity index was St2, which was obtained in March 2021 with a coefficient of 1.042 bits.org^{-1}. The lowest index value was measured at St4 in November 2020 (0.2606 bits.org^{-1}). The highest value at St1 was 1.029 in March 2021, and the lowest was 0.3486 in February 2021. At St2, the highest value was 1.042 in March 2021, and the lowest was 0.4581 in December 2020. The highest value was 1.009 at St3 in January 2021, and the lowest was 0.301 in October 2020. At St4, the high-

Table 5. Seasonal variation in saprobic index values among sampling stations.

SI	Aug 20	Sep 20	Oct 20	Nov 20	Dec 20	Jan 21	Feb 21	Mar 21	Apr 21	May 21	Jun 21	Jul 21	Mean
St1	*	2,8	2,4	2,4	2,3	2,3	2,3	2,2	2,2	*	*	*	2,4
St2	*	*	*	2,9	3,3	3,2	2,5	2,2	3,2	*	*	*	2,3
St3	2,3	2,3	3,5	3,5	2,6	2,9	2,7	3	3,1	3,1	3,4	2,7	2,7
St4	3	3,7	2,5	3,3	3,7	3,3	2,6	3	3,4	3,1	2,5	3,7	2,9
St5	3,7	3,7	2,7	3,3	3,7	3,3	3,1	2,8	4	3	2,8	3,8	2,8
St6	2,3	3,7	2,3	3	3,3	2,9	3,3	2,5	4	2,8	3	3,5	2,96

*Water shortage

Table 6. Similarity values of the stations in the Derinçay Stream determined from epiphytic diatoms.

	St1	St2	St3	St4	St5	St6
St1	1	0,68	0,65	0,36	0,35	**0,31**
St2		1	0,6	0,48	0,41	0,45
St3			1	0,63	0,66	0,57
St4				1	0,64	**0,75**
St5					1	0,72
St6						1

est value was 0.9319 in February 2021, and the lowest was 0.2606 in November 2020. The highest value at St5 was 0.8278 in March 2021, and the lowest was 0.2975 in July 2021. At St6, the highest value was 0.7952 in January 2021, and the lowest was 0.2764 in April and July 2021 (Fig. 2). Based on the data obtained regarding epiphyton in Derinçay Stream, it can be concluded that the conditions of the stream water are classified as heavily polluted (low diversity). This classification is supported by data on the diversity of epiphytic diatoms, which is classified as being at values < 1. According to previous research conducted by references (Wilhm, 1975; Soeprobowati et al., 2021), the value of epiphyton diversity can be grouped into three criteria: H' < 1 indicates heavily polluted water quality, 1 ≥ H' ≤ 3 indicates moderately polluted water quality, and H' > 3, clean water quality. However, Arsad et al. (2021) reported that the diversity index value obtained from the Brantas River in Indonesia is included in the moderate diversity group, which indicates that it exhibits less stable ecological pressure or an unhealthy (moderately polluted) aquatic environment. It was also pointed out by Hassan et al. (2023) that the Shannon-Weaver index values of epiphytic algae on *Phragmites* and *Ceratophyllum* plants were <4 and thus no serious pollution was recorded in the Diyala River. Considering the composition of epiphytic diatom communities and other indices, it was observed that these index results did not reflect the water quality and pollution levels of the Derinçay Stream stations very well.

According to changes in the Pielou evenness index, the highest value of 1 was observed at St3 in August 2020, October 2020, November 2020, and July 2021, at St4 in August 2020, October 2020, June 2021, and July 2021, and at St6 in August 2020, September 2020, October 2020, and December 2020. The lowest value of 0.2895 was recorded at St1 in February 2021. At St1, the highest value was 0.8201 in March 2021, and the lowest was 0.2895 in February 2021. At St2, the highest value was 0.9602 in December 2020, and the lowest was 0.8458 in November 2020. At St3, the highest value was 1 in August 2020, October 2020, November 2020, and July 2021, and the lowest was 0.4477 in June 2021. At St4, the highest value was 1 in August 2020, October 2020, June 2021, and July 2021, and the lowest was 0.5463 in November 2020. At St5, the highest value was 0.9796 in March 2021, and the lowest was 0.4941 in July 2021. At St6, the highest value was 1 in August 2020, September 2020, October 2020, and December 2020, and the lowest was 0.5247 in February 2021 (Fig. 3). Hassan and Shaawiat (2015) reported that an evenness index value of the Evenness index was <0.5, it represents the homogenisation of species. Besides, the evenness index of epiphytic algae in the Diyala River was found to be <0.5, indicating environmental stress in this river (Hassan et al., 2023).However, the study results of the Pielou evenness index (J') in the Derinçay stream ranged between 0.5 and 1 unit, indicating that the community balance in the epiphytic flora was good in most months.

According to the Margalef species richness index (d), the highest species richness value of 3.8 was observed in November 2020 at station 1 with 19 taxa, while the lowest value of 0.8 was recorded in November 2020 at St4 and in May 2021 at St5 with 2 taxa. At St1, the highest value was 3.815 in November 2020, and the lowest was 2.338 in December 2020. At St2, the highest value was 3.474 in March 2021, and the lowest was 1.243 in December 2020. At St3, the highest value was 3.391 bp in February 2021, and the lowest was 1.443 bp in October 2020. At St4, the highest value was 3.622 in February 2021, and the lowest was 0.8341 in November 2020. At St5, the highest value was 3.753 in March 2021, and the lowest was 0.8247 in May 2021. At St6, the highest value was 2.791 in August 2020, and the lowest was 0.9102 in April and July 2021 (Fig. 4).When

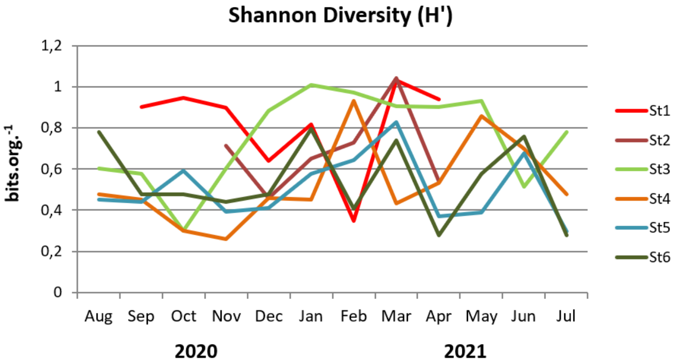

Figure 2. Shannon diversity index of epiphytic algae in the Derinçay stream.

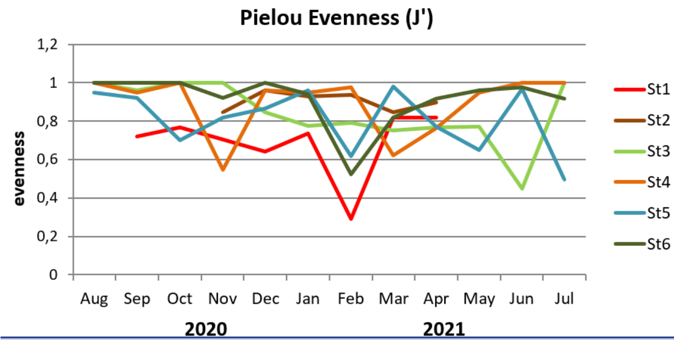

Figure 3. Pielou evenness of epiphytic algae in the Derinçay stream.

we examined the Margalef species richness seasonally, except for the 1st station, it was observed that autumn, spring, and summer had low species richness, while winter had high species richness. When evaluated on station level, the richest station in terms of species was the 1st station, and the lowest was the 5th station. The different values of the richness index revealed the variety of sites according to pollution impact. There was a significant difference between the upstream site and other sites due to the impact of pollution. Similar results were found in the Diyala River (Hassan et al., 2023) and Monjolinho River (Bere & Tundisi, 2011).

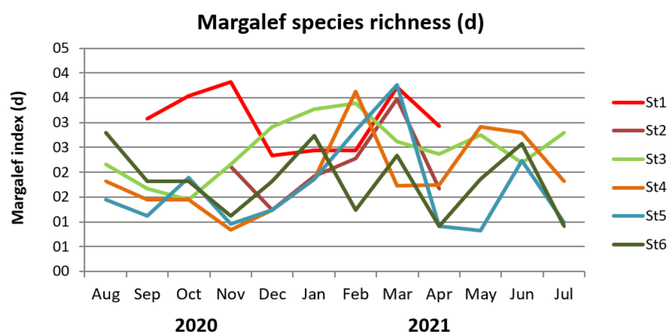

Figure 4. Margalef species richness of epiphytic algae in the Derinçay stream.

CONCLUSION

In this study, the distribution of epiphytic diatom species in the Derinçay stream and the physicochemical properties of water that influence this distribution were determined. It was found that most epiphytic algae commonly found in the Derinçay Stream comprise pollution-tolerant and facultative species. To assess the water quality of the Derinçay Stream, the Saprobic Index (SI), in which epiphytic species are classified, has been successful in reflecting organic pollution in certain stations in our study area, but deviations of the half-step positive direction were observed from the determined water quality classes. Another water quality assessment metric used in this study is the Trophic Diatom Index (TDI), calculated based on epiphytic diatoms in phytobenthos. While TDI has been successful in terms of overall results, it has been observed that it does not reflect the ecological structure of an area very well if there are not many organisms recorded in the area. In conclusion, despite these partial disadvantages, the phytobenthos-based SI and TDI, among the biological indices used to assess the water quality of Derinçay Stream, have provided good results in reflecting the current ecological structure of the stream, similar to physicochemical analyses and interpretations based on indicator diatom species.

Conflict of Interest: The authors declare that they have no competing interests.

Ethics Committee Approval: Ethics approval was not required for this study.

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