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Research Article Araştırma Makalesi

Determination of Biological Water Quality of Susurluk, Çapraz and Karadere Streams Using Macroinvertebrates and Biotic Indices

Susurluk Çayı, Çapraz Çay ve Karadere Çayının Biyolojik Su Kalitesinin Makrobentik Omurgasızlar ve Biyotik İndeksler Kullanılarak Belirlenmesi

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Abstract: The present study aimed to determine the water quality of Susurluk Stream, Çapraz Stream, and Karadere Stream by examining 5207 samples from 14 different stations in two different periods of 2021 (July and September), during which 37 families belonging to 15 order were identified. Physidae was identified as the dominant family for the first sampling period, while Baetidae was dominant for the second sampling period. BMWP Original, BMWP Turkish, BMWP Spanish, and ASPT biotic indices were used to assess the water quality of Susurluk, Çapraz, and Karadere Streams, and the index results were determined for each station for the first and second periods (July and September). Based on these index results, five different water quality categories were identified (Very Poor, Poor, Moderate, Good, Very Good). The obtained data were interpreted using t-tests and correlation analysis with the SPSS 2021 program.

Keywords
- Balıkesir
- Pollution
- BMWP
- Macrobenthos

Özet: Susurluk Çayı, Çapraz Çay ve Karadere Çayı'nın su kalitesinin belirlenmesi amacıyla 2021 yılının iki farklı döneminde (Temmuz ve Eylül) 14 farklı istasyondan 5207 örnek incelenmiş olup, 15 takıma ait 37 familya tespit edilmiş ve birinci örnekleme dönemi için Physidae, ikinci örnekleme dönemi için Baetidae familyaları en baskın familya olarak tespit edilmiştir. Susurluk, Çapraz ve Karadere çaylarının su kalitesinin ortaya konması amacıyla BMWP Orijinal, BMWP Turkish, BMWP Spanish ve ASPT biyotik indeksleri kullanılmış olup, her bir istasyonun birinci ve ikinci dönemleri için indeks sonuçları belirlenmiştir. Bu indeks sonuçlarına göre 5 farklı su kalitesi basamağı ortaya konulmuştur (Çok zayıf, Zayıf, Orta, İyi, Çok iyi). Elde edilen veriler SPSS 2021 programı kullanılarak t testi ve korelasyon analizi ile yorumlanmıştır.

Anahtar kelimeler
- Balıkesir
- Kirlilik
- BMWP
- Makrobentoz

1. INTRODUCTION

Northwest Anatolia's Susurluk Basin is one of the most significant basins in the country with a precipitation area of 22,400 km^2. Some of the water sources in the basin include the Orhaneli, Emet, Nilüfer, Mustafakemalpaşa, and Simav streams, along with the Karadere and Manyas Lakes. Due to the presence of borax facilities, poultry farms, leather and sugar factories within the basin and industrial waste from Bandırma district, pollution has reached critical levels in the area (Gürkan and Tekin-Özan, 2012).

Water pollution caused by industrial, organic-inorganic waste, sewage, and agricultural waste, which are among the significant pollutants, represents the chemical, biological, and physical changes in the waters (Atış, 2020).

One of the major contributors to water pollution is agricultural waste. The release of fertilizers and pesticides used during agricultural activities into water increases the concentration of nitrate (NO_3) and phosphate (PO_4) in the water. The increased concentration increases in algal populations, resulting in eutrophication in the aquatic environment (Çınar, 2008; Atış, 2020).

Studies conducted to determine water pollution involve both chemical and biological processes. In a recent research, the use of biological methods complements the results obtained from chemical methods (Dönmez & Yılmaz, 2015).

Bioindicator organisms, including macrobenthosis, provide crucial information about water quality and habitat based on their presence and abundance in aquatic environments. Due to their inability to move over long distances under changing ecological conditions and adverse circumstances, these organisms allow the detection of pollution over the long term (Akay, 2015).

Water quality assessment methods have emerged with the consideration of a biological perspective in studies aimed at determining water quality. Biotic indices are at the forefront of these methods. These indices are metric systems applied to reveal water quality, using data obtained from various stations. By considering the ecological condition of the study area, the presence, absence, abundance, sensitivity, and tolerance of species can be determined using biotic indices (Bahçeci, 2019).

There are many biological indices developed for different groups of organisms. One of the commonly used indices for macroinvertebrates is the Biological Monitoring Working Party Score System (BMWP), (Metcalfe, 1989). Many countries have adapted this index to their own invertebrate fauna in their rivers, with Spain being among the first to do so. The Spanish version of BMWP, known as "SpBMWP," is one of the most widely used indices, especially after the original BMWP (Alba & Sánchez, 1988). In Turkey, this index has also been adapted to create the "TRBMWP" (Turkish BMWP) biotic index (Kazancı, 2016).

The Average Score Per Taxon (ASPT) index is one of the most commonly used indices following BMWP. The ASPT index was calculated by dividing the total BMWP score obtained from the sampling point by the number of families (Metcalfe, 1989).

This study aims to determine the pollution levels of three Streams (Susurluk Stream, Çapraz Stream, Karadere Stream) located in the Marmara region through macrobenthos and family-based biotic indices, and to reveal the correlation between the biotic indices used.

2. MATERIAL and METHOD

In the present study, conducted between July and September 2021 on the Susurluk Stream, Çapraz Stream, and Karadere Stream, a total of 14 different stations were identified. The coordinates and altitude information for the designated stations are provided in Table 1. July is selected for sampling due to the high biological activity and for collecting mature multivoltine macrobenthos specimens. Sampling was also conducted in September due to the onset of rainfall at the end of the summer drought and the subsequent rise in water levels.

Various methods were used during sample collection. For instance, organisms living in areas with dense aquatic plants were collected using scoop nets and sieves, while in shallow and stagnant areas, the Surber Sampler along with the kick-sampling method was used. Samples from large stones in the water were collected by quickly removing samples from the surface of the stone using fine-tipped forceps. The macrobenthic samples collected from each station were sieved through sieves with different mesh sizes (0.5 mm, 1 mm, and 2 mm) to allow separation based on their sizes (Hauer & Lamberti, 2011). They were then transferred to falcon tubes and eppendorf tubes of different sizes and brought to the laboratory for fixation in 70% ethanol and subsequent identification. The collected samples were identified using a Leica MZ12.5 stereo microscope, and photographs of the samples were taken with a Leica DMC 2900 camera attached to the stereo microscope.

The families identified from the sampling areas were subjected to four different biotic indices, and the data were interpreted using t-tests and correlation analysis with the SPSS-2021 program.

During the diagnosis of the samples, literature sources such as Elliot (1988), Friday (1988), Bouchard (2004), Smith (1989), Gürlek (2019), Gürlek (2009), Macan (1976), Savage (1990), Sağlam (2004), Nesemann & Neubert (1999), Dobson (2013), Soltesz (1996), and (Holzenthal, et al., 2007) were consulted.

Table 1. Coordinates and altitude information of the sampling areas.

Station	Location Name	Geographic Coordinates (N, E)	Altitude a.s.l (m)
1	Susurluk Stream	39°36'31.62"N, 28°5'14.55"E	40m
2	Susurluk Stream	39°48'49.56"N, 28°10'49.12"E	33m
3	Susurluk Stream	39°51'53.11"N, 28°9'36.06"E	50m
4	Susurluk Stream	39°53'32.84"N, 28°9'36.06"E	48m
5	Susurluk Stream	39°55'3.36"N, 28°9'56.79"E	59m
6	Çapraz Çay Stream	39°59'32.92"N, 28°10'35.61"E	30m
7	Çapraz Çay Stream	40°3'16.56"N, 28°11'58.11"E	16m
8	Çapraz Çay Stream	40°11'48.42"N, 28°21'43.21"E	24m
9	Çapraz Çay Stream	40°12'18.95"N, 28°25'59.15"E	10m
10	Çapraz Çay Stream	40°16'43.07"N, 28°25'5.41"E	19m
11	Çapraz Çay Stream	40°18'16.95"N, 28°26'51.95"E	15m
12	Çapraz Çay Stream	40°20'23.02"N, 28°28'3.36"E	10m
13	Karadere Stream	40°8'2.96"N, 28°7'43.78"E	20m
14	Karadere Stream	40°7'50.20"N, 28°2'56.20"E	17m

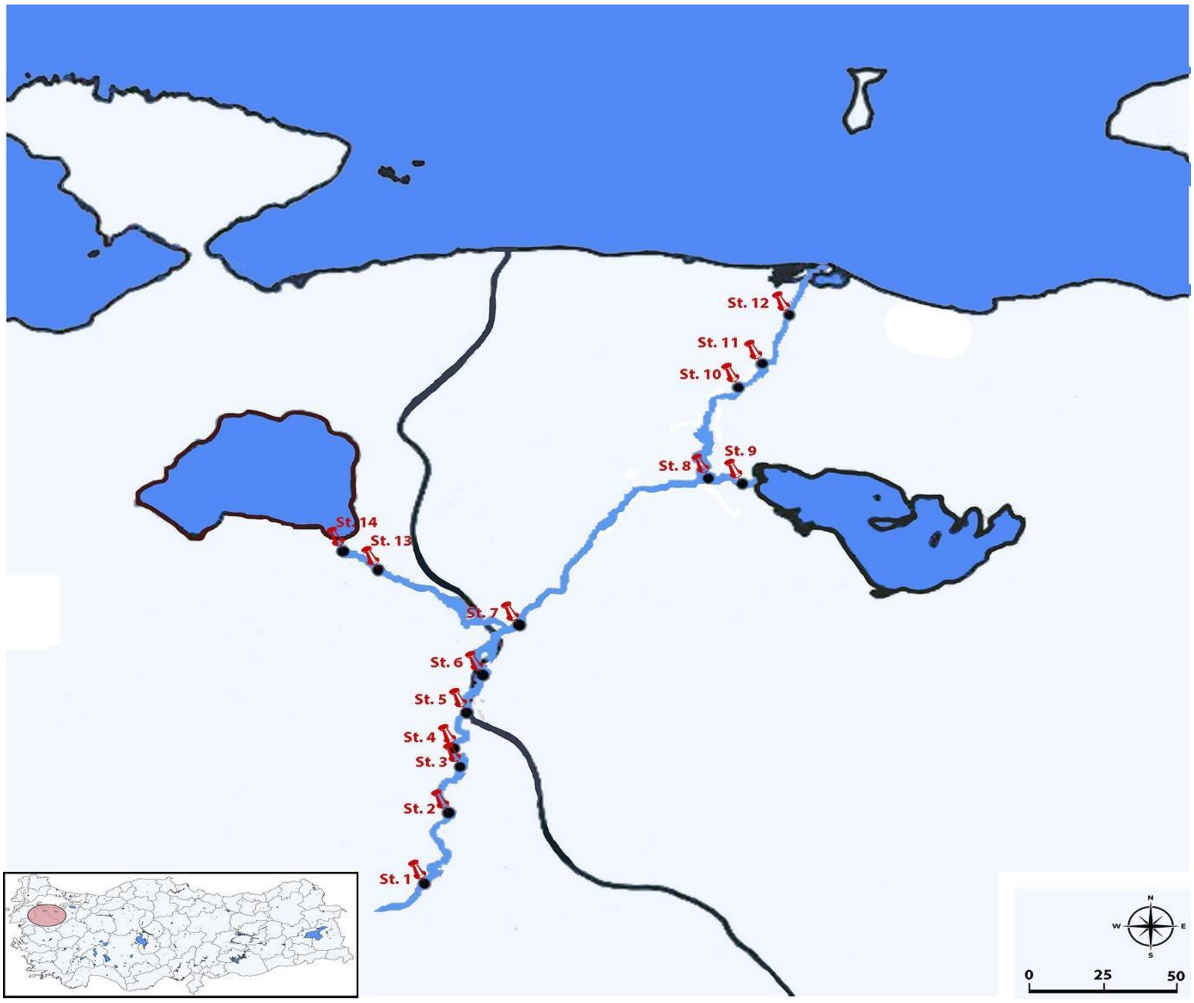

Figure 1. Locations of all stations on the map.

3. RESULTS

During field studies conducted in July and September 2021, a total of 37 benthic macroinvertebrate families were detected in Susurluk Stream, Karadere and Çapraz Stream. These families include Erpobdellidae, Glossiphonidae, Unionidae, Hydrobidae, Lymnaeidae, Melanopsidae, Physidae, Planorbidae, Viviparidae, Asellidae, Gammaridae, Baetidae, Caenidae, Calopterygidae, Coenagrionidae, Cordulegasteridae, Gomphidae, Libellulidae, Corixidae, Gerridae, Hydrometridae, Mesovelidae, Naucoridae, Nepidae, Pleidae, Curculionidae, Dytiscidae, Haliplidae, Hydrophilidae, Hygrobidae, Noteridae, Ceratopogonidae, Chironomidae, Sciomyzidae, Simuliidae, Stratiomydae, and Hydropsychidae. The class most represented with identified families was Insecta according to the diagnoses.

As a result of field studies, 37 families belonging to 15 taxa were identified at 14 different stations. Four different biotic indices were applied to the identified families. The index results are provided in Table 2. The lowest and highest values obtained from the station are indicated in bold.

Table 2. The index results obtained from the stations.

		BMWP(Orijinal)	BMWP(Turkish)	BMWP(Spanish)	ASPT
Station 1	1st period	-	-	-	-
	2nd period	**13***	**9***	**9***	**6,5***
Station 2	1st period	59	49	50	4,5
	2nd period	34	31	33	4,25
Station 3	1st period	44	42	37	**4,8***
	2nd period	15	15	15	3,75
Station 4	1st period	32	33	28	4,0
	2nd period	40	42	35	5,0
Station 5	1st period	**31***	**31***	**26***	4,4
	2nd period	31	29	29	3,8
Station 6	1st period	49	45	48	4,4
	2nd period	20	26	26	4,0
Station 7	1st period	41	35	35	4,5
	2nd period	46	30	40	5,1
Station 8	1st period	40	37	33	4,4
	2nd period	28	30	27	4,0
Station 9	1st period	**63***	54	45	4,5
	2nd period	**64***	**63***	**49***	4,5
Station 10	1st period	33	**31***	28	4,1
	2nd period	42	44	43	4,6
Station 11	1st period	45	45	42	**4,09***
	2nd period	31	26	29	3,8
Station 12	1st period	58	**59***	46	4,4
	2nd period	16	26	21	**3,2***
Station 13	1st period	59	52	**52***	4,2
	2nd period	25	21	21	4,1
Station 14	1st period	61	51	50	4,6
	2nd period	17	12	11	4,25

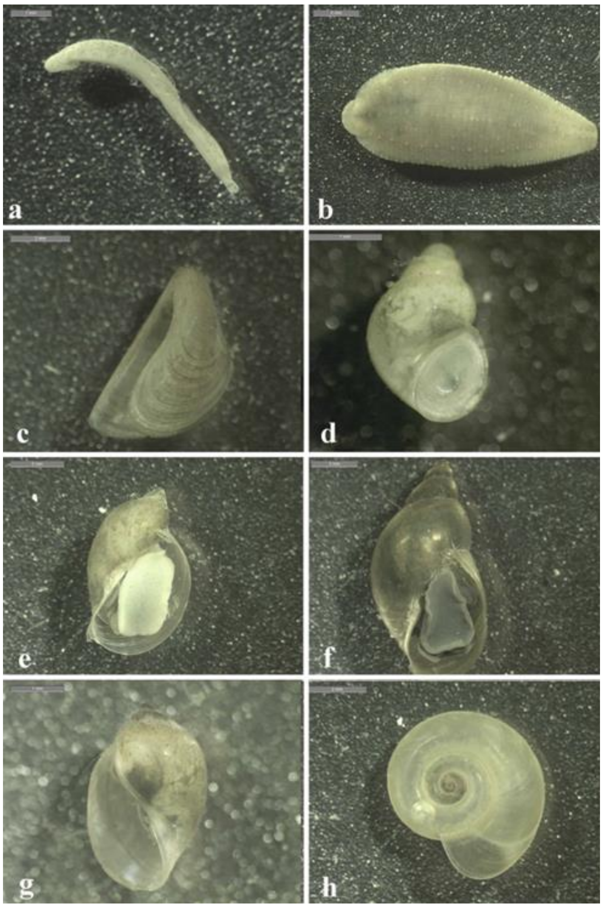

Figure 2. Families detected during the study.; a) Erpobdellidae, b) Glossiphonidae, c) Unionidae, d) Hydrobidae, e) Lymnaeidae, f) Melanopsidae, g) Physidae, h) Planorbidae.

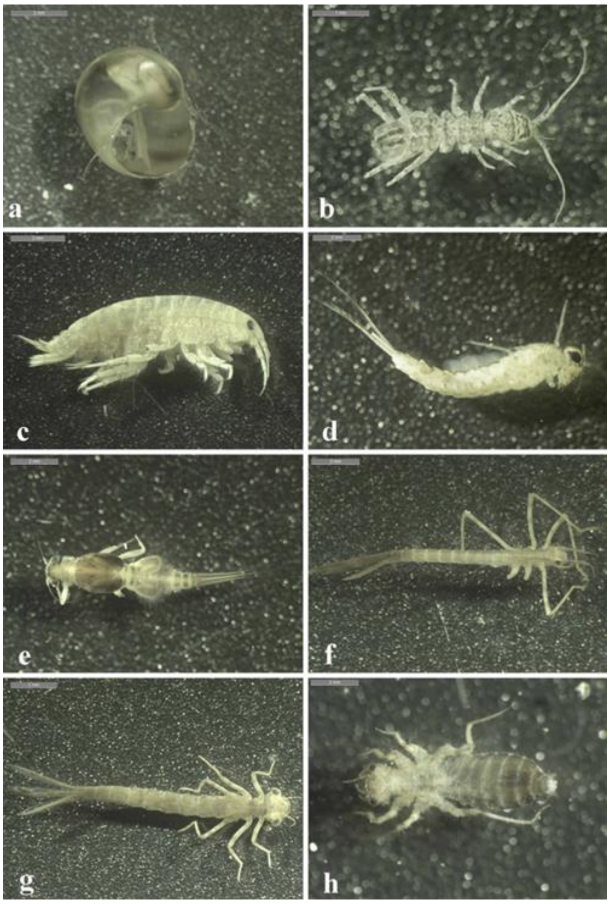

Figure 3. Families detected during the study; a) Viviparidae, b) Asellidae, c) Gammaridae, d) Baetidae, e) Caenidae, f) Calopterygidae, g) Coenagrionidae, h) Cordulegasteridae.

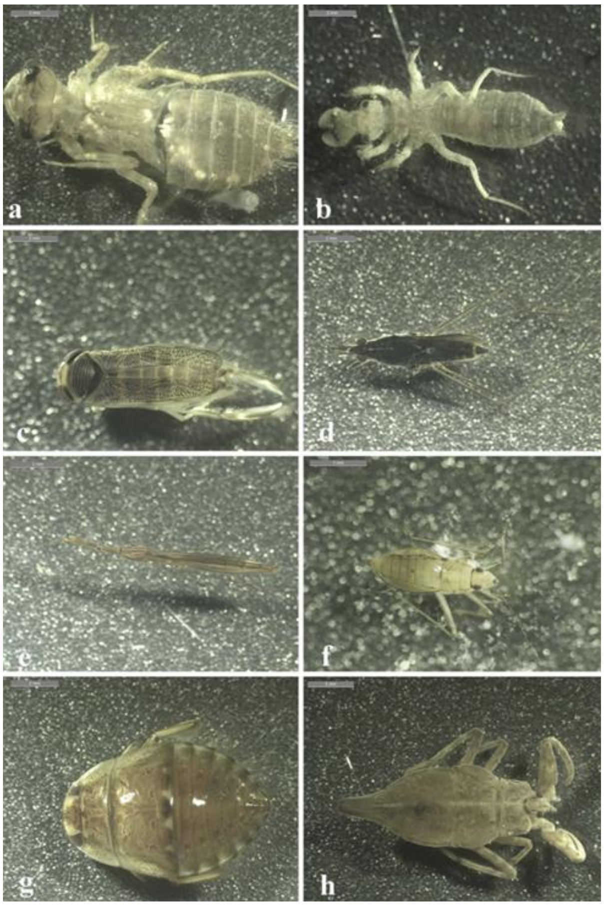

Figure 4. Families detected during the study*;* a) Gomphidae, b) Libellulidae, c) Corixidae, d) Gerridae, e) Hydrometridae, f) Mesovelidae, g) Naucoridae, h) Nepidae.

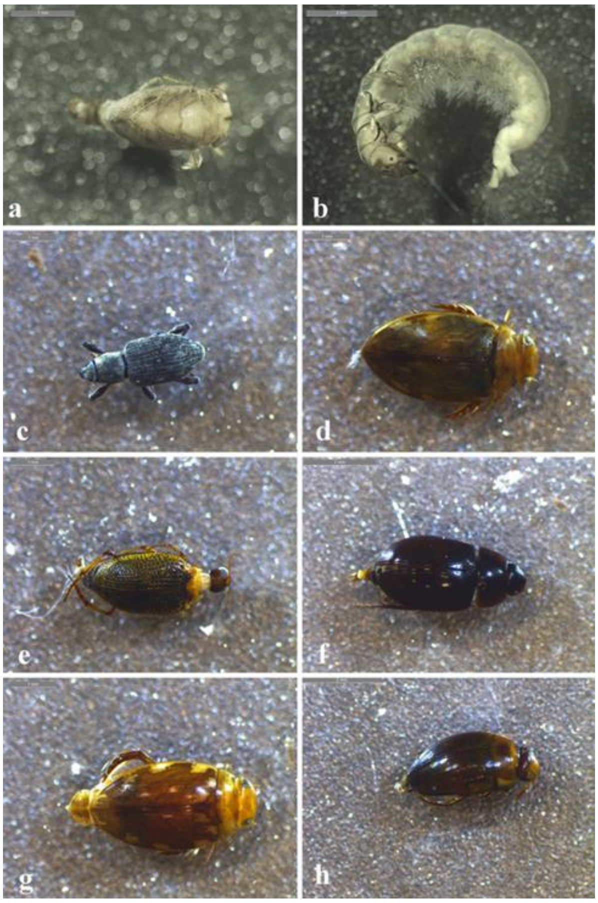

Figure 5. Families detected during the study*;* a) Pleidae, b) Hydropsychidae, c) Curculionidae, d) Dytiscidae, e) Haliplidae, f) Hydrophilidae, g)Hygrobidae, h) Noteridae.

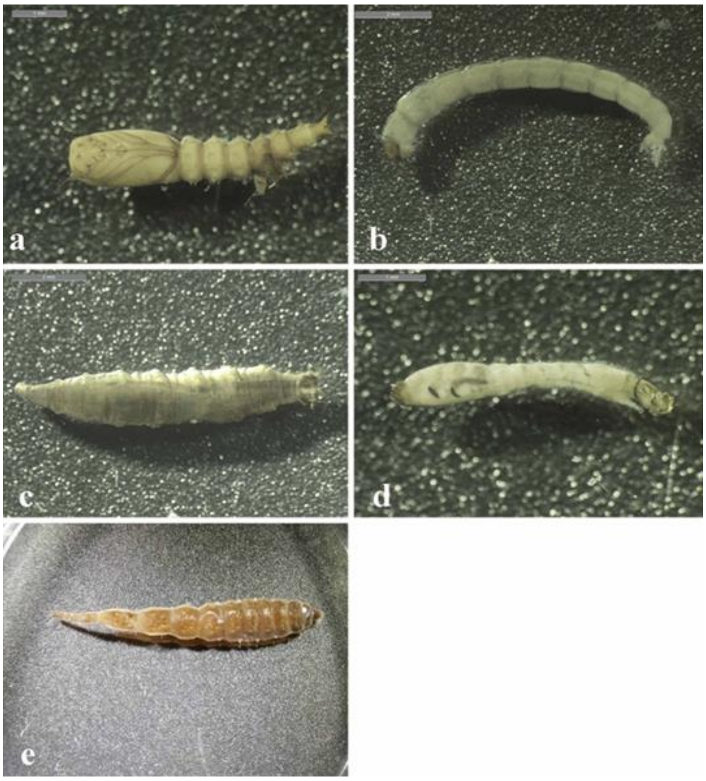

Figure 6. Families detected during the study; a) Ceratopogonidae (pupa), b) Chironomidae, c) Sciomyzidae, d) Simuliidae, e) Stratiomydae.

The percentage ratios of all identified orders resulting from the field studies are provided below (Figure 7). The order represented by the highest number of families (7 families) at the designated sampling points is Hemiptera, followed by Coleoptera and Gastropoda with 6 families each. The data related to water quality parameters from the index studies conducted in a total of 14 stations during the first and second periods are presented in Table 2.

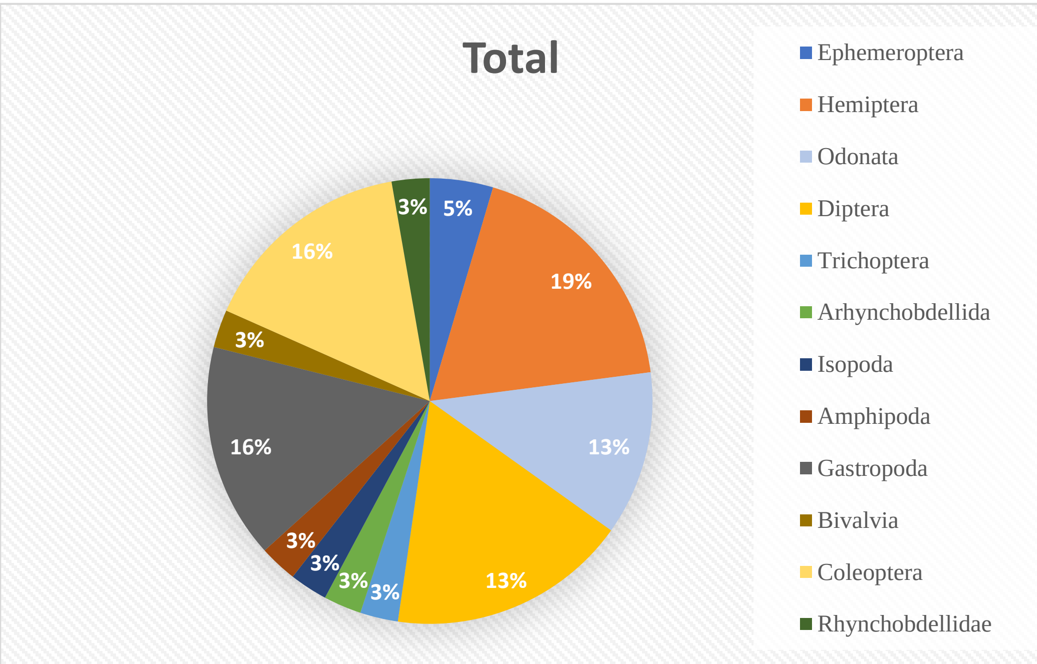

Figure 7. Percentage dominance of all orders detected during the first and second sampling periods.

Table 3. Water quality classes of the stations.

		BMWP (Original)	BMWP (Turkish)	BMWP (Spanish)	ASPT
Station 1	1st period	-	-	-	-
	2nd period	Very poor	Very poor	Very poor	Very good
Station 2	1st period	Moderate	Moderate	Moderate	Moderate
	2nd period	Poor	Poor	Poor	Moderate
Station 3	1st period	Poor	Moderate	Moderate	Moderate
	2nd period	Very poor	Poor	Very poor	Poor
Station 4	1st period	Poor	Poor	Poor	Moderate
	2nd period	Poor	Moderate	Poor	Good
Station 5	1st period	Poor	Poor	Poor	Moderate
	2nd period	Poor	Poor	Poor	Poor
Station 6	1st period	Poor	Moderate	Moderate	Moderate
	2nd period	Very poor	Poor	Poor	Moderate
Station 7	1st period	Poor	Poor	Poor	Moderate
	2nd period	Poor	Poor	Moderate	Good
Station 8	1st period	Poor	Poor	Poor	Moderate
	2nd period	Poor	Poor	Poor	Moderate
Station 9	1st period	Moderate	Moderate	Moderate	Moderate
	2nd period	Moderate	Moderate	Moderate	Moderate
Station 10	1st period	Poor	Poor	Poor	Moderate
	2nd period	Poor	Moderate	Moderate	Moderate
Station 11	1st period	Poor	Moderate	Moderate	Moderate
	2nd period	Poor	Poor	Poor	Poor
Station 12	1st period	Moderate	Moderate	Moderate	Moderate
	2nd period	Very poor	Poor	Poor	Poor
Station 13	1st period	Moderate	Moderate	Moderate	Moderate
	2nd period	Very poor	Poor	Poor	Moderate
Station 14	1st period	Moderate	Moderate	Moderate	Moderate
	2nd period	Very poor	Poor	Very poor	Moderate

During the sampling period, no samples could be obtained from Station 1. This station, located on the Susurluk River, has been significantly exposed to pollutants due to its location. The waste discharged into the river by nearby livestock farms is one of the major factors causing a decrease in the abundance of macrobenthos populations in the environment and even complete disappearance during discharge periods.

The results of the t-test and correlation analysis applied to the data are presented in Table 4 and 5.

Table 4. Independent Samples Test.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
BMWPORIGINAL	Equal variances assumed	,133	,719	2,325	26	,028	13,786	5,929	1,598	25,974
	Equal variances not assumed			2,325	25,337	,028	13,786	5,929	1,582	25,989
BMWPTURKISH	Equal variances assumed	,090	,767	2,111	26	,045	11,429	5,413	,302	22,555
	Equal variances not assumed			2,111	25,934	,045	11,429	5,413	,301	22,556
BMWPSPANISH	Equal variances assumed	,183	,672	1,932	26	,064	9,429	4,879	-,601	19,458
	Equal variances not assumed			1,932	25,303	,065	9,429	4,879	-,614	19,471
ASPT	Equal variances assumed	,005	,942	-,739	26	,467	-,283	,383	-1,070	,504
	Equal variances not assumed			-,739	22,754	,468	-,283	,383	-1,076	,510

Table 5. Correlation Analyzes.

		BMWPORIGINAL	BMWPTURKISH	BMWPSPANISH	ASPT
BMWPORIGINAL	Pearson Correlation	1	,936**	,952**	,604**
	Sig. (2-tailed)		,000	,000	,001
	N	26	26	26	26
BMWPTURKISH	Pearson Correlation	,936**	1	,925**	,471*
	Sig. (2-tailed)	,000		,000	,015
	N	26	26	26	26
BMWPSPANISH	Pearson Correlation	,952**	,925**	1	,540**
	Sig. (2-tailed)	,000	,000		,004
	N	26	26	26	26
ASPT	Pearson Correlation	,604**	,471*	,540**	1
	Sig. (2-tailed)	,001	,015	,004	
	N	26	26	26	26

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

4. DISCUSSION

Today, the rapidly increasing industrialization in Susurluk Stream and its surroundings, the proximity of agricultural areas to the Stream, the spillage of agricultural pesticides into the stream directly or through groundwater, the proximity of some parts of the Susurluk Stream to the highway, domestic pollutants, the local people's use of the stream and its surroundings for recreational purposes, and the unconscious pollution left behind are the main causes of pollution. The waste left behind is the most important factor that has caused the pollution in the Susurluk stream to seriously increase in recent years.

Similar to many other macrobenthic invertebrate studies conducted in our country, Insecta was identified as the class with the highest number of individuals in this study, as reported in previous works (İmamoğlu, 2000), (Yorulmaz, et al., 2003), (Kalyoncu, 2005), (Baydar, 2020), (Ertaş, et al., 2021), (Kılçık &Tekin Özan, 2024).

When the dominance values of benthic macroinvertebrates were examined according to stations, the Physidae family was the most dominant family with rates of 33%, 46%, 50%, 40% and 29%, respectively, in the 3rd, 4th, 6th, 8th and 9th stations in the 1st sampling period; during the 2nd sampling period, the Baetidae family was the most dominant family with rates of 65%, 79%, 47%, 55% and 33% at the 2nd, 3rd, 4th, 5th and 9th stations, respectively.

In the first sampling period, no samples were obtained from the 1st station. This station on the Susurluk Stream has been exposed to significant pollutants due to its location. The discharge of waste from the livestock farms near the station is one of the major factors causing the disappearance of life in the environment. In the second sampling period, a total of 46 individuals were identified, and these individuals belonged only to the Dytiscidae and Hydrophilidae families. The dense algal growth present at the station during the first sampling period has transformed into a livable environment through auto-remediation in the second sampling period.

5. CONCLUCION

All field studies revealed that the 1st station had the least number of samples collected. This result highlights the pollution level at the station. The results of the BMWP indices also support this pollution. However, according to the ASPT index result, the station is considered to be very good in terms of pollution. The exceptionally good ASPT index result is thought to be due to the detection of only two families at the station. Since the ASPT index is obtained by dividing the BMWP score by the number of families at the station, the value turned out to be high due to the detection of only two families, leading to a conclusion of very good water quality in terms of pollution. In stations with a low number of families like this, it is believed that the ASPT index may not work accurately, and other indices should also be considered.

In a general sense, when all stations are examined, the study results indicate that the dominant organisms are Gastropoda, Odonata, and Isopoda. In many stations, pollution levels in the second sampling period are worse compared to the results of the first sampling period. The variation between the two periods, influenced by a decrease in the number of organisms and families in the polluted environment, indirectly affects the score values, reflecting on the results of biotic indices. Additionally, the absence of some families obtained in the second sampling period from the BMWP score table is also a significant factor contributing to this conclusion.

When the samples taken from the Susurluk Stream are evaluated, it is observed that there are differences between the stations, but the overall water quality is deemed POOR. The discrepancy arises in the ASPT index results at the 2nd station of the Susurluk Stream, where the first period's result is good and the second period's result is very good, contradicting with the other index results. Since the ASPT index is obtained by dividing the BMWP value by the number of families, it is believed that the scarcity of families has influenced this result.

The stations 6 to 12 on the Çapraz Stream, similar to the Susurluk Stream, can be characterized as having POOR water quality. In some stations where the pollution level is determined to be MODERATE, the observation of families not included in the index tables and not taken into account is thought to lead to different results. Additionally, the proximity of sampling points on the Çapraz Stream to residential areas and the poor use of recreational areas in the vicinity can be said to have a significant impact on the results obtained.

At the 13th and 14th stations on the Karadere Stream, the significant difference in water quality between the two periods is attributed to the lower number of families sampled during the second sampling period. While a total of 29 different families were identified during the first sampling period from both stations, only 10 different families were identified during the second sampling period. It is believed that the decrease in the number of organisms in the polluted environment has affected the score values and is reflected in the biotic index results.

All these studies indicate that the three different biotic indices used (BMWP Original, SpBMWP, TrBMWP) do not yield entirely identical results, demonstrating that the indices do not fully support each other. The discrepancies may also be attributed to the absence of some families obtained from the stations in the BMWP original index table, contributing to these conclusions.

BMWP Original (t:2.325, $p<0.05$) and BMWP Turkish (t: 2.111, $p<0.05$) indices show a statistically significant difference as their Significant values are less than 0.05. However, BMWP Spanish (t: 1.932, $p>0.05$) and ASPT (t: -0.739, $p>0.05$) indices do not exhibit a statistically significant difference since their Significant values are greater than 0.05.

The correlation test indicates that the BMWP Original index is associated with the other indices. BMWP Original index shows positive correlations with BMWP Turkish at 0.936, with BMWP Spanish at 0.952, and with ASPT at 0.604, all with a 99% confidence interval (<0.001) for each. BMWP Turkish index is correlated with BMWP Spanish at 0.925 and with ASPT at 0.471, with a 99% confidence interval (<0.01) for Spanish and 95% (<0.05) for ASPT. A positive correlation of 0.540 is found between BMWP Spanish and ASPT indices, with a 99% confidence interval (<0.01).

Numerically, an increase in the score value suggests an increase in the other indices. It is believed that BMWP Original, BMWP Turkish, and BMWP Spanish indices are derivatives of each other, with a 99% confidence interval. The narrower 95% confidence interval between BMWP Turkish and ASPT indices suggests that the BMWP Turkish index might have been determined within a limited range and could have areas for further development.

When the results of the study are evaluated, it becomes evident how crucial it is to have a new index for Türkiye and to create a comprehensive score table covering the Turkish limnofauna. The similarity in water qualities of all stations, except for a few, according to the BMWP Turkish and Spanish results, suggests that the Spanish version of the BMWP index can also be utilized in biotic index studies conducted in Türkiye.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

Literature: BÖ; Methodology: NE; Data analysis: BÖ; Manuscript writing: NE, BÖ; Supervision: NE. All authors approved the final draft.

ETHICAL STATEMENTS

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available in the supplementary material to this article.

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