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Evaluation of the Water Quality of Kura-Aras River Basins, Transboundary Rivers of Türkiye, According to Some Biotic Indices

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Abstract: In this study aimed in the Kura-Aras river basin, which is the transbourdary system of Türkiye, to determine water quality by using some physicochemical parameters and macroinvertebrates. In the spring and autumn periods, benthic macroinvertebrates were collected by standard D-Frame Net and Ekman grab from stations. A total of 30 stations were selected along the basin. In this study, following Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), Simpson Diversity Index, Shannon-Weaver Diversity Index, Margalef Diversity Index. It was determined that the most dominant group was Insecta and the rarest group was Oligochaeta in the Kura- Aras River basin. As a result of the evaluation of the selected stations in the basin in terms of physicochemical parameters, it was determined that they showed 2nd and 3rd class water characteristics in terms of PO_4-P and NH_4–N. According to BMWP and ASPT biotic indexes, it has been determined that it has 3rd and 4th class quality properties.

Keywords: Benthic invertebrates, biotic indices, freshwater, physicochemical parameters.

Türkiye'nin Sınıraşan Akarsularından Kura-Aras Nehir Havzaları Su Kalitesinin Bazı Biyotik İndekslere Göre Değerlendirilmesi

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Öz: Bu çalışmada, Türkiye'nin sınır ötesi sistemi olan Kür-Aras havzasında bazı fizikokimyasal parametreler ve makroomurgasızlar kullanılarak su kalitesinin belirlenmesi amaçlanmıştır. İlkbahar ve sonbahar dönemlerinde, istasyonlardan standart D-Frame Net ve Ekman kepçesi ile bentik makroomurgasızlar toplanmıştır. Havza boyunca toplam 30 istasyon seçilmiştir. Bu çalışmada sırasıyla Biyolojik İzleme Çalışma Grubu (BMWP), Her Taksonun Ortalama Değeri (ASPT), Simpson Çeşitlilik İndeksi, Shannon-Weaver Çeşitlilik İndeksi, Margalef Çeşitlilik İndeksi takip edilmiştir. Kura-Aras Nehri havzasında en baskın grubun Insecta, en nadir grubun Oligochaeta olduğu belirlenmiştir. Havzada seçilen istasyonların fizikokimyasal parametreler açısından değerlendirilmesi sonucunda PO_4-P ve NH_4–N açısından 2. ve 3. sınıf su özelliği gösterdikleri belirlenmiştir. BMWP ve ASPT biyotik indekslerine göre 3. ve 4. sınıf özelliklere sahip olduğu belirlenmiştir.

Anahtar kelimeler: Bentik omurgasızlar, biyotik indeks, içsu, fizikokimyasal parametreler.

INTRODUCTION

Turkey has 25 river basins, including 5 transboundary river systems: Çoruh, Meriç, Kura, Aras, Euphrates, and Tigris rivers. The Kura and Aras river systems are vital for the Transcaucasia region's biodiversity hotspot due to their high species diversity and sensitive ecosystems (UNDP, 2007). The Kura-Aras basin, which covers Azerbaijan, Georgia, Iran and a part of Turkey and the whole of Armenia, is the water resource that countries benefit from for agricultural products and industrial activities from the source to the downstream (Zeeb, 2010). However, since the second half of the 20th century, the amount and quality of water have deteriorated due to untreated wastewater, pesticides and fertilizers, industrial wastewater, climate change, population growth, mineral deposits, and other polluting factors (Zeeb, 2010; FAO, 2017; Yeşilbaş & Kapan 2021).

Urban and industrial wastewater, as well as surface runoff from agricultural areas, have a negative impact on the physical, chemical, and biological processes of aquatic environments. This pollution can result in a decline or disappearance of aquatic organisms (Adalı, 2014). In order to assess water quality in lotic systems, hydromorphological and physicochemical analyses provide instant information, while biological data gives a medium to long-term information (Sukatar et al., 2006). The use of bioindicators and the development of different indices for evaluating the ecological status of waters has increased in recent years, particularly in invertebrate groups. Invertebrate groups are commonly used in bioindicator studies due to their ease of sampling, wide availability, inexpensive equipment, pollution tolerance at different levels, and ease of diagnosis at the family level. This approach is recommended by the European Union Water Environment Directive (De Pauw & Hawkes, 1993; Zeybek et al., 2014).

There have been various studies conducted on water pollution, biodiversity, and water management in the Kura-Aras river systems (UNDP, 2007; Özbay & Kılınç, 2008; Zeeb, 2010; Kükrer et al., 2014; Çiçek & Sungur Birecikligil, 2016; Yıldız, 2017; Kılıç et al., 2018; Kırpık et al., 2019; Çelekli et al., 2019; Arslan & Mercan, 2020; Yeşilbaş & Kapan, 2021; Aliyev, 2022; Mercan et al., 2022). While most studies have focused on lotic systems, some have investigated invertebrate fauna and lake ecosystems using indices (Özbay & Kılınç, 2008; Kükrer et al., 2014; Kılıç et al., 2018; Çelekli et al., 2019; Kırpık et al., 2019; Arslan & Mercan, 2020; Mercan et al., 2022). There are many streams and a few lakes within the Turkish borders of the Kura-Aras basin. The aim of this study is to assess water quality in Kura-Aras basin rivers using physicochemical parameters and biotic indices, such as BMWP, ASPT, Shannon Wiener, and Simpson diversity indices.

MATERIAL AND METHOD

Study Area: The study area is focused on the Kura-Aras rivers, which are transboundary rivers passing through Turkey, Georgia, Armenia, and Azerbaijan, and eventually empty into the Caspian Sea. The Kura River originates from the "Erzurum-Kars" section of the Eastern Anatolia Region in Turkey and is separated from the Çoruh River basin and the Aras River basin by mountain ranges. The total lenght of the Kura River is 1515 km. The Aras River, on the other hand, rises from the Bingöl Mountains within the borders of Erzurum province and flows towards Armenia, collecting all the waters of Tekman Plateau and Hasankale (Pasinler) Stream. Approximately 548 km of the Aras River flows within Turkey (Coşkun, 2020). The sampling points for the study are shown in Figure 1, which was created using the QGIS 2.18 software package.

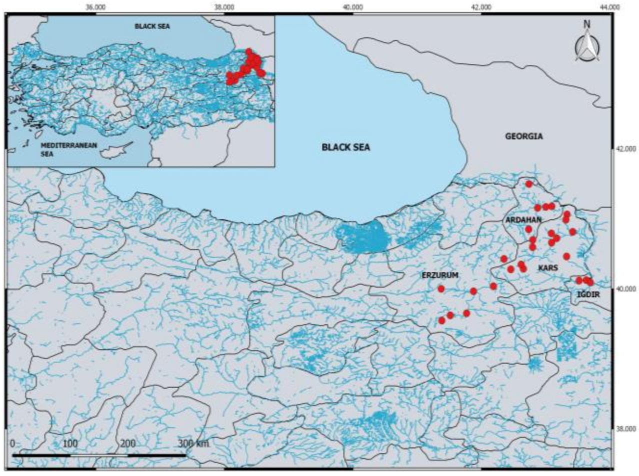

Figure 1. Map of sampling points

Sampling and Physiochemical Parameter Measurement: In order to collect samples for the research, 30 distinct stations within the Kura-Aras river basin were chosen. Two sampling sessions were carried out in October 2020 and May 2021. The sampling process involved utilizing a hand net with size of 30x30 cm and a mesh size of 250 microns. This net was used to collect organisms from various habitats, following the flow of the stream. Some organisms were removed from stones using forceps and pipettes. Samples were fixed with 70% alcohol in the field and stored in alcohol again in the laboratory after separation. The samples were categorized and diagnosed using loop and Leica brand stereomicroscopes. Water temperature (°C), pH, and dissolved oxygen (DO) were measured in the field using an HQ 40D water meter. Concurrent with macroinvertebrate samplings, water samples were collected and analyzed for PO_4–P and NH_4–N parameters using a spectrophotometer. All analyses were conducted following standard methods (APHA, 1998).

Evaluation of Data: The sampling points were selected based on the criteria for choosing operational monitoring sites as specified in WFD Annex V 1.3.2. Water quality was assessed based on physicochemical parameters using SWQMR. Biotic indices such as Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), Simpson's Diversity Index, Shannon-Wiener Diversity Index, and Margalef Diversity Index were applied on benthic invertebrates. The Bray-Curtis similarity index was used to evaluate similarity among the samples. Canonical Correlation Analysis (CCA) was used to assess the relationship between environmental parameters and biological data.

Compliance with Ethical Standards: This article does not contain any studies with human participants performed by any of the authors. Ethics committee approval is not required for the article.

RESULTS AND DISCUSSION

Information on sampling points is given in Table 1.

Table 1. Location and coordinate information of sampling stations.

	Station Names	Province/Town	Coordinates
K1	Süngütaşı Stream	Kars/Sarıkamış	40.2785 N 42.4561 E
K2	Kınavur Stream	Ardahan/Yalnızçam	41.197 N 42.612 E
K3	Kura River	Ardahan/Göle	40.8511 N 42.7341 E
K4	Gaziler Stream	Erzurum/ Şenkaya	40.4276 N 42.3505 E
K5	Bozkuş Stream	Kars/Selim	40.5948 N 42.7952 E
K6	Tuzluca (Aras River)	Iğdır/Tuzluca	40.1247 N 43.63 E
K7	Fehmiharabesi Stream (Susuz Waterfall)	Kars/Susuz	40.7920 N 43.0870 E
K8	Doğruyol Stream	Ardahan/Damal	41.063 N 43.3306 E
K9	Kars Stream	Kars/Çamçavuş	40.6601 N 43.0903 E
K10	Kızılgeçit Stream	Erzurum/Tekman	39.6213 N 41.5146 E
K11	Derinöz Stream	Kars/Digor	40.4622 N 43.3237 E
K12	Aras River	Iğdır/Tuzluca	40.1172 N 43.5182 E
K13	Çamçavuş Dam	Kars/ Çamçavuş	40.723 N 43.170 E
K14	Kaplıca Stream	Erzurum/Tekman	40 N 41.3733 E
K15	Endek Stream	Erzurum/Horasan	40.0375 N 42.1856 E
K16	Kars Stream	Kars/Sarıkamış	40.3487 N 42.6174 E
K17	Ölçek Stream	Ardahan/Altaş	41.1575 N 42.8739 E
K18	Carci Stream	Kars/Arpaçay	40.8141 N 43.4184 E
K19	Tozlukomu Stream	Erzurum/Karayazı	39.6512 N 41.7685 E
K20	B-20 Channel	Iğdır/ Tuzluca	40.0923 N 43.6926 E
K21	Karaman Stream	Ardahan/Posof	41.4976 N 42.7388 E
K22	Köprüköy Stream	Erzurum/Köprüköy	39.9656 N 41.8754 E
K23	Keklik Stream	Kars/Sarıkamış	40.2865 N 42.6517 E
K24	Karanlık Mağara Stream	Erzurum/Tekman	39.5464 N 41.3824 E
K25	Kara Stream (Devil's Castle Stream))	Ardahan/Çıldır	41.1790 N 43.0935 E
K26	Tavşan Stream	Kars/Arpaçay	40. 8496 N 43.3404 E
K27	Çığırgan Stream	Kars/Merkez	40.699 N 42.7977 E
K28	Toros Stream	Ardahan/Yalnızçam	41.095 N 42.505 E
K29	Çöt Stream	Ardahan/Hanak	41.1704 N 43 E
K30	Göldalı town Stream	Ardahan/Göldalı	40.987 N 43.313 E

Physicochemical Parameters: Temperature is a crucial factor for aquatic life as it can affect various physiological processes and nutrient requirements. While some invertebrate groups are more tolerant of high temperatures, there are also stenothermal groups like Plecoptera that have narrower temperature ranges (Wetzel, 2001; Tanyolaç, 2004). According to Burgmer et al. (2007), the average temperature increase caused by climate change can significantly impact benthic living assemblages in lentic systems. In this study, temperatures ranged between 9.4-17.85°C, with the highest values recorded at stations K20 (17.85°C) and K3 (15.7°C), and the lowest values at stations K19 (9.4°C) and K11 (10.2°C). These temperature measurements fall within the appropriate ranges for seasonal conditions (Table 2).

The amount of oxygen in water can vary depending on factors such as temperature, salt levels, and biological events. A study conducted by Ertaş and Yorulmaz, (2021) in Kelebek Stream identified the species of Amphipoda present in areas with low pollution. Other studies have shown that Chironomidae species have high tolerance ranges and are not greatly affected by changes in factors such as temperature and dissolved oxygen (Moisan & Pelletier, 2008; Zeybek, 2017; Kalyoncu & Zeybek, 2011). Ephemeroptera, Plecoptera and Tricoptera taxa are known to be sensitive to changes in oxygen concentrations and are considered indicators of high water quality (Lenat, 1993; Merritt et al., 1978), while Diptera and Oligochaeta species can survive in low oxygen concentrations (Ode et al., 2005; Ertaş & Yorulmaz, 2021). In measurements taken in the Kura-Aras river system, dissolved oxygen levels ranged from 10.16-7.85 mg/L (Table 2). The pH levels in surface waters can range from 6 to 9, and pollutants can cause changes in pH. Different species have varying tolerances to pH levels. Certain invertebrate groups, such as Coleoptera, Chironomidae, Plecoptera, and Tricoptera, are resistant to high pH levels (Tanyolaç, 2004). However, Oligochaeta species have lower taxa richness, biomass, and density in acidic waters (Ilyashuk, 1999). In this study measuring pH levels between 7.73 and 8.85 at different stations (Table 2), there were no significant changes in pH. Some invertebrate families, such as Hydropsychidae, Ryacophilidae, Taeniopterygidae, Culicidae, Chironomidae and Dytiscidae, were found at stations with pH levels greater than 8.4 in this study. Nitrogenous compounds can enter natural waters through allochthonous or autochthonous ways and their concentration increases due to domestic and industrial wastes (Tanyolaç, 2004). In this study found NH_4-N levels ranging from 1.11-0.24 mg/L in a basin where agriculture and animal husbandry are common, with the highest and lowest values at stations K30 and K8, respectively. PO_4-P levels also vary based on factors such as detergent, geological structure, and waste material (Tanyolaç, 2004), with maximum and minimum values ranging from 0.71-0.07 mg/L at stations K6 and K11, respectively. The study identified that nitrogen load primarily came from animal husbandry, cesspool effluent and agricultural fertilizers, while phosphorus load came from commercial fertilizers in high amounts and livestock activities (Yontar, 2009). It has been reported that the nitrogen load is higher in the provinces of Kars and Ardahan, where animal husbandry is more intense, and the phosphorus load is higher in the province of Iğdır, where agricultural activity is more intense (Yontar, 2009). Water quality classes in the stations were evaluated according to SWQMR, showing 2nd and 3rd Class water characteristics for NH_4-N concentration and 3rd and 4th

Class water characteristics for PO_4-P concentration (Table 2). The studies found a positive correlation between organic matter, ammonium, and phosphate levels and the abundance of Oligochaeta and Diptera (Rashid & Pandit, 2014; Armendariz, 2011). In this study, the families Tipulidae, Chironomidae, and Culicidae were dense in stations with high PO_4-P concentration.

Table 2. Average measurements of physicochemical parameters (T: Temperature; DO: Dissolved oxygen; pH: Power of hydrogen; NH_4-N: Amonium; PO_4-P: Phospate.

Station Code	Stations/Parameters	T °C	Class	DO (mg/L)	Class	pH	Class	NH_4-N (mg/L)	Class	PO_4-P (mg/L)	Class
K1	Süngütaşı Stream	11.75±1.9	1	9.1±0.56	1	7.91±0.26	1	0.535±0.13	2	0.285±0.02	3
K2	Kınavur Stream	11.5±0.7	1	8.15±0.35	1	7.75±0.49	1	0.335±0.1	2	0.655±0.23	4
K3	Kura River	15.7±3.2	1	7.915±0.4	2	8.07±0.52	1	0.585±0.06	2	0.375±0.06	3
K4	Gaziler Stream	12.1±0.1	1	9.15±0.35	1	8.05±0.21	1	1.02±0.25	3	0.37±0.05	3
K5	Bozkuş Stream	12.8±2.1	1	8.61±0.69	1	8.26±0.22	1	0.975±0.61	2	0.415±0.17	3
K6	Tuzluca Stream (Aras River)	13.5±0.1	1	8.5±0.14	1	8±0.28	1	0.975±0.14	2	0.71±0.24	4
K7	Fehmiharabesi Stream (Susuz Waterfall)	11.25±0.2	1	8.55±0.35	1	7.73±0.18	1	0.8785±0.46	2	0.34±0.16	3
K8	Doğruyol Stream	13.4±0.1	1	8.45±0.34	1	8.45±0.07	1	0.245±0.09	2	0.345±0.09	3
K9	Kars Stream	11.25±1.6	1	8.3±0.55	1	7.95±0.91	1	0.84±0.26	2	0.405±0.03	3
K10	Kızılgeçit Stream	11.65±0.2	1	8.93±0.24	1	8.015±0.12	1	0.935±0.27	2	0.685±0.03	4
K11	Derinöz Stream	10.25±0.9	1	8.5±0.1	1	8.1±0.7	1	0.525±0.07	2	0.0705±0.05	2
K12	Aras River (Mainbody)	11.35±2.6	1	8.59±0.97	1	8.48±0.16	1	0.9±0.32	2	0.2355±0.007	3
K13	Çamçavuş Dam	12.7±0.1	1	8.4±0.28	1	8.25±0.63	1	0.85±0.57	2	0.675±0.09	4
K14	Kaplıca Stream (Tekman)	11.2±0.1	1	9.2±0.14	1	8.15±0.35	1	0.5±0.19	2	0.315±0.07	3
K15	Endek Stream	12.3±0.1	1	8.65±0.77	1	7.8±0.14	1	0.59±0.09	2	0.31±0.042	3
K16	Kars Stream (Sarıkamış)	10.8±0.1	1	8.1±0.42	1	8.25±0.21	1	0.305±0.04	2	0.135±0.03	2
K17	Ölçek Stream	11.9±0.5	1	8.58±0.25	1	8.365±0.61	1	1.095±0.04	3	0.575±0.19	3
K18	Carci Stream	10.75±0.07	1	8.75±0.21	1	8.75±0.07	1	0.385±0.1	2	0.28±0.09	3
K19	Tozlukomu Stream	9.4±0.1	1	9.05±0.35	1	8.05±0.21	1	0.3±0.04	2	0.335±0.13	3
K20	B-20 Channel	17.85±3.4	1	8.26±0.65	1	8.285±0.16	1	0.666±0.78	2	0.079±0.043	2
K21	Karaman Stream	11.4±0.1	1	8.8±0.56	1	7.95±0.21	1	0.585±0.1	2	0.39±0.042	3
K22	Köprüköy Stream	10.9±0.8	1	8.6±0.21	1	8.25±0.49	1	0.7±0.53	2	0.137±0.13	2
K23	Keklik Stream	11.2±1.2	1	10.16±2.21	1	8.195±0.007	1	0.389±0.06	2	0.11±0.08	2
K24	Karanlık Cave Stream	10.5±0.1	1	8±0.14	1	8.85±0.07	1	0.34±0.09	2	0.22±0.02	2
K25	Kara Stream	10.95±0.3	1	9.33±0.09	1	7.795±0.14	1	0.72±0.43	2	0.355±0.02	3
K26	Tavşan Stream	10.7±1.9	1	8.15±0.07	1	8.15±0.63	1	0.405±0.04	2	0.300.175±	3
K27	Çığırgan Stream (Kura River)	12.4±0.1	1	8.7±0.1	1	8.35±0.07	1	0.98±0.36	2	0.63±0.26	3
K28	Toros Stream (Çatalköprü Stream)	10.45±0.2	1	9.2±0.56	1	8.3±0.56	1	0.3±0.02	2	0.102±0.08	2
K29	Çöt Stream	11.8±0.7	1	8.95±0.49	1	8.85±0.07	1	0.585±0.07	2	0.39±0.08	3
K30	Göldalı Stream	12.4±0.1	1	7.85±0.07	2	8.45±0.49	1	1.11±0.32		0.515±0.007	3
SWQMR	**Class I**	**25**		**8**		**6.5-8.5**		**0.2**		**0.02**	
	Class II	**25**		**6**		**6.5-8.5**		**1**		**0.16**	
	Class III	**30**		**3**		**6-9**		**2**		**0.65**	
	Class IV	**>30**		**<3**		**Out of 6-9**		**>2**		**>0.65**	

Bentic Invetebrates Data: This study aimed to investigate the zoobenthic invertebrate fauna of the Kura-Aras river systems, and a total of 4568 individuals belonging to 51 families were collected. The maximum number of individuals was found in the Ephemeroptera (1412), Diptera (1058) and Malacostraca (944) groups, respectively (Table 3). The number of individuals collected in the spring period was higher than in the fall period. Insecta was the most dominant group among the taxa, while Oligochaeta was the rarest. Within the Insecta group, Ephemeroptera individuals were the most common, accounting for 30.91% of the total, while Anisoptera individuals were the least encountered, accounting for only 0.04% (Figure 2). The text detailed the findings of a study conducted on water quality within the basin, utilizing two biotic indices: the BMWP and ASPT. The BMWP scores ranged from 5 to 126, and the ASPT scores ranged from 2.5 to 7.2. The highest BMWP scores were found at stations K28, K3, and K16, while the lowest BMWP scores were found at stations K20, K30, and K24. The water quality classification based on the BMWP scores mostly showed 3rd and 4th class water characteristics for the stations. The highest ASPT scores were found at K16 and K10, while the lowest ASPT scores were found at K20 and K21. The water quality classification based on ASPT scores mostly showed 2nd and 3rd class water characteristics for the stations (Table 4). The previous studies that have used BMWP and ASPT indices to evaluate water quality in other basins (Kazancı et al., 2010; Kalyoncu & Zeybek, 2011; Kazancı et al., 2015; Zeybek, 2017; Serdar & Verep, 2018; Baytaşoğlu & Gözler, 2021; Yorulmaz & Ertaş, 2021; Ertaş & Yorulmaz, 2022; Ertaş et al., 2023;) and describes the lack of studies on invertebrate groups in the Kura-Aras basin, except for two studies on macrozoobenthic and Oligochaeta fauna in lakes (Arslan & Mercan, 2020; Mercan et al., 2022).

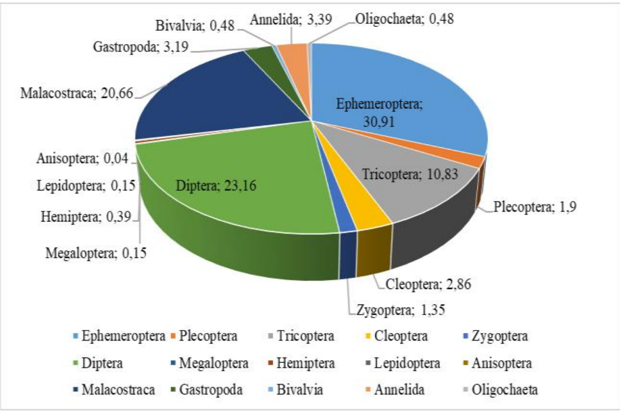

Figure 2. Dominance of taxon at the stations.

Table 3. List of families detected at stations.

Phylum	Ordo	Familya	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19	K20	K21	K22	K23	K24	K25	K26	K27	K28	K29	K30
Arthropoda	Ephemeroptera	Heptageniidae	*	*	*			*	*	*			*	*		*		*							*			*		*		
		Baetidae		*	*	*	*	*		*	*		*	*	*	*	*	*	*	*	*		*	*	*			*		*	*	
		Leptophlebiidae						*										*										*				
		Caenidae			*			*			*		*				*															
		Prosopistomidae						*																								
		Ephemerellidae											*																			
		Sıphlonuridae																												*		
	Plecoptera	Taeniopterygidae								*																						
		Perlodidae							*									*												*		
		Perlidae														*		*												*		
		Pteronarcyidae																*														
		Nemouridae																*														
	Tricoptera	Lepidostomidae							*																							
		Hydropsychidae	*		*	*	*	*	*	*		*	*	*		*	*		*	*	*	*		*			*	*	*	*	*	
		Psychomiidae									*	*			*					*												
		Sericostomatidae																					*									
		Leptoceridae																							*							
		Ryacophilidae			*					*									*											*		
		Goeridae																												*		
		Polycentropodidae			*																											
		Limnephilidae			*							*																		*		
	Coleoptera	Hygrobiidae		*																												
		Dytiscidae		*	*															*			*							*		
		Gyrinidae										*																				
		Elmidae		*	*				*							*		*			*				*		*			*	*	
		Hydraenidae																*												*		
		Elminthidae																			*											

	Zygoptera	Calopterygidae (Ariidae)			*							*	*																			
		Coenagridae		*	*																					*			*		
	Diptera	Tipulidae		*	*			*	*				*			*	*				*			*	*	*	*	*		*	*	*
		Drosophilidae						*																								
		Culicidae		*						*	*												*									
		Tabanidae							*								*				*			*								*
		Psychodidae							*																							
		Chironomidae	*	*	*		*		*	*	*		*	*		*	*		*	*			*		*	*	*	*	*	*	*	*
		Muscidae					*														*			*								
		Ceratopogonidae																								*						
	Megaloptera	Sialidae										*																				
	Hemiptera	Corixidae		*															*								*			*		
	Lepidoptera	Pterophoridae																				*										
	Anisoptera	Cordulidae																												*		
	Malacostraca	Gammaridae	*	*	*	*	*		*		*		*						*	*	*			*	*		*	*	*	*	*	
		Asellidae			*				*							*													*	*		
Mollusca	**Gastropoda**	Planorbiidae		*	*						*				*				*	*			*	*			*				*	
		Lymnaeidae		*	*						*		*		*	*											*				*	
	Bivalvia	Corbulidae																	*	*												
		Sphaeriiidae																												*		
Annelida		Hirudinae	*	*									*			*					*			*		*	*	*		*	*	*
		Glossiphonidae																					*									
Oligochaeta		Lumbricidae		*															*	*			*		*					*		
		Oligochaeta				*							*																			

Table 4. Evaluation of stations according to index score values.

	S	N	d	J'	H'(loge)	BMWP	ASPT	BMWP class	ASPT class
K1	5	121	0,8341	0,726	1,686	22	4,4	4	3
K2	15	258	2,521	0,7572	2,958	58	3,8	3	4
K3	17	306	2,795	0,7291	2,98	88	5,1	2	2
K4	4	80	0,6846	0,7169	1,434	16	4	4	3
K5	5	114	0,8446	0,534	1,24	19	3,8	4	4
K6	9	77	1,842	0,8973	2,844	47	5,8	3	2
K7	11	218	1,857	0,7242	2,505	61	5,5	3	2
K8	7	254	1,084	0,6127	1,72	38	5,4	4	2
K9	8	503	1,125	0,5669	1,701	32	4	4	3
K10	6	28	1,501	0,8453	2,185	37	6,1	4	2
K11	12	118	2,306	0,9212	3,303	53	4,4	3	3
K12	4	26	0,9208	0,8879	1,776	20	5	4	2
K13	5	101	0,8667	0,6503	1,51	18	4,5	4	3
K14	10	144	1,811	0,7304	2,426	51	5,1	3	2
K15	6	200	0,9437	0,5776	1,493	26	4,3	4	3
K16	9	76	1,847	0,8564	2,715	65	7,2	3	1
K17	9	157	1,582	0,7968	2,526	35	3,8	4	4
K18	9	165	1,567	0,7125	2,259	35	3,8	4	4
K19	9	97	1,749	0,7792	2,47	42	4,6	3	3
K20	2	11	0,417	0,9457	0,9457	5	2,5	5	4
K21	8	298	1,229	0,5624	1,687	27	3,3	4	4
K22	8	202	1,319	0,727	2,181	30	3,7	4	4
K23	8	147	1,403	0,693	2,079	45	5,6	3	2
K24	4	46	0,7836	0,7919	1,584	15	3,7	5	3
K25	10	108	1,922	0,8946	2,972	41	4,1	3	3
K26	8	121	1,46	0,6783	2,035	42	5,2	3	2
K27	4	46	0,7836	0,9322	1,864	15	3,7	4	4
K28	22	381	3,534	0,7771	3,465	126	5,7	1	2
K29	9	151	1,594	0,7484	2,372	38	4,2	4	3
K30	4	14	1,137	0,9212	1,842	13	4,3	4	3

The highest number of families was found at K28, K3, K2 while the lowest number of families was found at K20. The stations with the highest diversity, based on the Shannon index, were K28, K11, and K5, while the stations with the highest regularity index was K20 (Table 4). The Shannon–Weaner index value ranges from >3 it indicates clean water, 1–3 indicates moderate pollution, <1 indicates heavy pollution (Wilhm & Dorris, 1968). Shannon diversity index value in the basin was between 1-3. This indicates that the stations in Kura-Aras basin have moderate pollution. The cluster analysis showed that mostly Iğdır and Kars stations were grouped and Ardahan stations were grouped together (Figure 3).

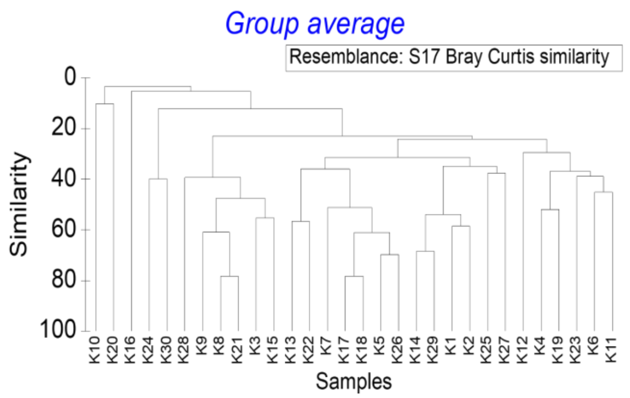

Figure 3. Bray Curtis similarity diagram

The CCA analysis revealed that certain families, such as Prosopistomidae, Sialidae, Hygrobiidae, Drosophiidae, and Gyrinidae, showed a positive correlation with PO_4-P in the studied lakes in the Kura-Aras river basin (Figure 4). However, previous research (Minaya et al., 2013; Kaboré et al., 2016) has shown that families like Ephemeroptera, Trichoptera, and Plecoptera are good indicators of uncontaminated waters, while families such as Baetidae, Caenidae, and Hydropsychidae are more tolerant to changes in environmental conditions. The presence of Baetidae, Caenidae, and Hydropsychidae in polluted stations in the studied area suggests their resistance to current conditions. Furthermore, previous studies (Mauricio da Rocha et al., 2010) have suggested that families such as Gyrinidae, Dytiscidae, Hydrophilidae, and Notonectidae reflect ecological and geological changes. In this study, the families of Gyrinidae and Dytiscidae were found to be positively correlated with PO4-P and potentially more resistant to increased concentrations. Mercan et al. (2022), in their study in 3 different lakes in the Aras river basin, identified 47 taxa belonging to macrozoobenthic fauna and reported the dominant group in these lakes as Chironomidae and Oligochaeta. Arslan and Mercan (2020), recorded 22 species in the study in which they determined the Oligochaeta fauna of Çıldır Lake and emphasized that these species are new records for the lake. Chironomidae and Oligochaeta, which are known to have high ecological tolerance, were detected in a total of 23 stations during this study, stations with both clean and polluted water characteristics.

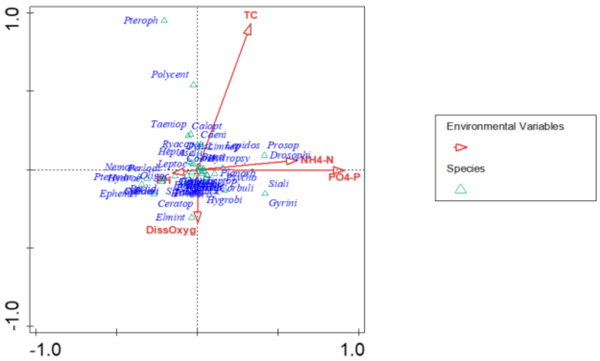

Figure 4. CCA dendogram in which families and environmental parameters are evaluated together.

CONCLUSION

In this study, benthic invertebrate fauna of the Kura-Aras basin were identified at the family level and stations were evaluated according to biotic indices. Physicochemical parameters were measured simultaneously with invertebrate groups and evaluated according to SWQMR classes. Both physicochemical parameters and biotic index score values showed that the quality of the basin was moderately polluted.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

REFERENCES

Adalı, N. (2014). *Su kirliliği açısından hassas alanların ve su kalitesi hedeflerinin belirlenmesi ile hassas alanların yönetimine ilişkin esaslar*, Orman ve Su İşleri Bakanlığı, Uzmanlık Tezi, Ankara, 170.

Aliyev, SI. (2022). The environment of macrozoobenthos of Kura-Aras basın rivers. *Advances in Biology & Earth Sciences*, ***7***, 152-167.

APHA, (1998). *Standard Methods for the Examination of Water and Wastewater. 20th Edition, American Public Health Association*, American Water Works Association and Water Environmental Federation, Washington DC.

Armendariz, L.C., Capitulo, A.R. & Ambrosio, E.S. (2011). Relationships between the spatial distribution of oligochaetes (Annelida, Clitellata) and environmental variables in a temperate estuary system of South America (Rio de la Plata, Argentina). *New Zeland Journal of Marine Freshwater Research*, ***45***, 263-279.

Arslan, N. & Mercan, D. (2020). The aquatic oligochaete fauna of Lake Çıldır, Ardahan-Kars, Turkey, including an up-dated checklist of freshwater annelids known to occur in the country. *Zoosymposia*, ***17***, 53-76. DOI: 10.11646/zoosymposia.17.1.8

Baytaşoğlu, H. & Gözler, A.M. (2021). Evaluation of water quality of Çoruh River Basin (Turkey) using some biotic indices. *Ege Journal of Fisheries and Aquatic Sciences*, ***38***, 399-409. DOI: 10.12714/egejfas.38.4.01

Burgmer, T., Hillebrand, H. & Pfenninger, M. (2007). Effects of climate-driven temperature changes on the diversity of freshwater macroinvertebrates. *Oecologia*, ***151***, 93-103.

Coşkun, S. (2020). Aras-Kura Kapalı Havzasının Ortalama Sıcaklık, Yağış ve Akım Verilerinin Trend Analizi (Türkiye), *The Journal of International Social Sciences*, ***30***, 29-42

Çelekli, A., Kayhan, S., Lekesiz, Ö., Toudjani, A.A. & Çetin, T. (2019). Limno-ecological assessment of Aras River surface waters in Turkey: application of diatom indices. *Environment Science & Pollution Research*, ***26***, 8028-8038.

Çiçek, E. & Sungur, S. (2016). Ichthyofauna of the Turkish parts of Kura-Aras River Basin. *FishTaxa*, ***1***, 14-26.

De Pauw, N. & Hawkes, HA. (1993). Biological Monitoring of River Water Quality. in: Walley, W.J., Judd, S. (Eds.), *River Water Quality Monitoring and Control*. 87-112 Aston University, Birmingham.

Ertaş, A. & Yorulmaz, B. (2021). Assessing water quality in the Kelebek Stream branch (Gediz River Basin, West Antolia of Turkey) using physicochemi-cal and macroinvertebrate-based indices. *Aquatic Research*, ***4***, 260-278. DOI: 10.3153/AR21020

Ertaş, A., Öztürk, S., Yaşartürk, M. & Yorulmaz, B. (2023). Biological Assesment of Demirci Stream in Gediz River Basin (West Anatolia of Turkey) and Comparative Performance of Benthic Macroinvertebrate-Based Metrics, *Biologia*, ***78***, 1103-1112

Ertaş, A. & Yorulmaz, B. (2022). Comparative Performance of the Indices Used for Bioassessmentof Water Quality of Sangı Stream

(West Anatolia, Turkey). *Russian Journal of Ecology*, ***53***, 312-327

FAO (Food and Agriculture Organization of the United Nations) (2017). *Water pollution from agriculture: A global review (executive summary).* Food and Agriculture Organization of the UN. http://www.fao.org/3/a-i7754e.pdf.

Ilyashuk, B.P. (1999). Littoral Oligochaete (Annelida: Oligochaeta) communities in neutral and acidic lakes in the Republic of Karelia, Russia. *Boreal Environtal Research*, ***4***, 277-284.

Kaboré, I., Moog, O., Alp, M., Guenda, W. & Koblinger, T. (2016). Using macroinvertebrates for ecosystem health assessment in semi-arid streams of Burkina faso. *Hydrobiologia*, ***766***, 57-74. DOI: 10.1007/s10750-015-2443-6

Kalyoncu, H. & Zeybek, M. (2011). An application of different biotic and diversity indices for assessing water quality: A case study in the Rivers Çukurca and Isparta (Turkey). *African Journal of Agricultural Research*, ***6***,19-27.

Kazancı, N., Ekingen, P., Türkmen, G., Ertunç, Ö., Dügel, M. & Gültutan, Y. (2010). Assesment of ecological quality of Aksu Stream (Giresun, Turkey) in Eastern Black Sea Region by using Water Framework Directive (WFD) methods based on benthic macroinvertebrates. *Review of Hydrobiology*, ***3***,165-184.

Kazancı, G. N, Türkmen, G. & Başören, Ö. (2015). Application of BMWP and using benthic macroinvertebrates to determine the water quality of a transboundary running water Çoruh River Turkey. *Review of Hydrobiology*, ***8***, 119-130.

Kılıç, N.K, Caner, H, Erginal, A.E, Ersin, S., Selim, H.H. & Kaya, H. (2018). Environmental changes based on multi-proxy analysis of core sediments in Lake Aktaş, Turkey: preliminary results. *Quaternary International*, 486, 89-97.

Kırpık, M.A, Tanrıkulu, D. & Altunoğlu, M.K. (2019). Aktaş (Ardahan) Gölü ve Çevresinin Faunistik Yapısı. *Kafkas Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 12, 89-95.

Kükrer, S., Seker, S., Abaci, Z.T. & Kutlu, B. (2014). Ecological risk assessment of heavy metals in surface sediments of northern littoral zone of Lake Çildir, Ardahan. Turkey. *Environmental Monitoring Assessment*, ***186***, 3847-3857.

Lenat, D. (1993). Freshwater Biomonitoring and Benthic Macroinvertebrates. *Journal of the North American Benthological Society*, ***12***, 220-222. DOI: 10.2307/1467358

Mauricio Da Rocha, J.R, Almeida, J.R., Lins, G.A. & Durval, A. (2010). Insects as Indicators of Environmental Changing and Pollution: A Review of Appropriate Species and Their Monitoring. *Holos environment*, ***10***, 250-262.

Mercan, D., Arslan, N., Çamur-Elipek, B., Ertorun, N. & Odabaşı, D.A. (2022). Aras Nehri havzasındaki (Kuzeydoğu Türkiye) üç gölün (Çıldır, Aktaş ve Aygır) makrozoobentik fauna yapısının ilk değerlendirilmesi. *Aquatic Research*, ***5***, 307-318. DOI: 10.3153/AR22030

Merritt, R., Cummins, K. & Berg, M., (1978). *An Introduc-tion to the Aquatic Insects of North America.* 1st ed.; Ken-dall/Hunt Publishing Company: Dubuque, Iowa, U.S.A.

Minaya, V., McClain, M.E., Moog, O., Omengo, F.S. & Gabriel, A. (2013). Scale-dependent effects of rural activities on benthic macroinvertebrates and physico-chemical characteristics in headwater streams of the Mara River, Kenya. *Ecological Indicators*, ***32***, 116-122. DOI: 10.1016/j.ecolind.2013.03.011

Moisan, J. & Pelletier, L. (2008). Guide de surveillance bi-ologique basée sur les macroinvertébrés benthiques d'eau douce du Québec-cours d'eau peu profonde à substrat grossier. Direction de Suivi de l'Etat de l'Environnement, Ministère du Développement Durable de l'Environnement et des Parcs. 86p.

Ode, P.R, Rehn, A.C. & May, J.T. A. (2005). Quantitative tool for assessing the integrity of southern coastal California streams. *Environmental Management*, ***35***, 493-504. DOI: 10.1007/s00267-004-0035-8.

Özbay, H. & Kılınç, S. (2008). Limnological studies on the transboundary Turkish soda lake: Lake Aktaş. *Fresenius Environmental Bulletin*, ***17***, 722-731.

Rashid, R. & Pandit, A.K. (2014). Macroinvertebrates (Oligochaetes) as indicators of pollution: A review. *Journal of Ecology and the Natural Environment*, ***6***, 140-144. DOI: 10.5897/JENE2014.0443

Serdar, O &Verep, B. (2018). The Investigation of Water Quality of İyidere and Çiftekavak Streams Using Physico-Chemical and Biotic Indexes. *Int. J. Pure Appl. Sci.*, ***4***, 61-71.

Sukatar, A, Yorulmaz, B., Ayaz, D. & Barlas, M. (2006). Emiralem Deresi'nin (İzmir-Menemen) Bazı Fiziko-Kimyasal ve Biyolojik (Bentik Makroomurgasızlar) Özelliklerinin İncelenmesi, *Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü Dergisi*, ***10***, 328-333.

Tanyolac, J. (2004). *Limnology* (3rd edition) (in Turkish), Ankara: Hatipoğlu Press. ISBN: 975-752-746-6

UNDP/GEF. (2007). *Kura-Aras River Basin Transboundary Diagnostic Analysis*. TDA report.

Wetzel, R.G. (2001). *Limnology Lake and Reservoir Ecosystems*. Academic Press, San Diego. Third Edition. Acade-mic Press, San Diego. DOI: 10.1016/C2009-0-02112-6

Wilhm, J.L. & Dorris, T.C. (1968). Biological parameters for water quality criteria. *BioScience*, ***18***, 477-81. DOI: 10.2307/1294272

Yeşilbaş, N. & Kapan, K. (2021). Kura ve Aras Nehirlerinin Azerbaycan Aran (Kür-Araz) Bölgesi Açısından Jeoekonomik Önemi. *Avrasya incelemeleri Dergisi*, ***10***, 167-192

Yıldız, D. (2017). Transkafkasya'nın Sınıraşan Su Sorunları. *World Water Diplomacy & Science News*, 10001, 1-25.

Yontar, B. (2009). *Aras Havzası'nda yayılı kirletici kaynakların belirlenmesi ve yönetim önerileri*. Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul, 116s.

Yorulmaz, B. & Ertaş, A. (2021). Water quality asssesment of Selendi stream and comparative performance of the indices based on benthic macroinvertebrates and physical parameters. *Biologia*, ***76***, 2599-2607.

Zeeb, S. (2010). Adaptation to Climate Change in the Kura-Aras River Basin, River Basin Snapshot Draft for Discussion, Competence Center Water and Waste Management, 46.

Zeybek, M., Kalyoncu, H., Karakaş, B. & Özgül, S. (2014). The use of BMWP and ASPT indices for evaluation of water quality according to macroinvertebrates in Değirmendere Stream (Isparta, Turkey). *Turkısh journal of Zoology*, ***38***, 603-613

Zeybek, M. (2017). Macroinvertebrate-based biotic indices for evaluating the water quality of Kargı Stream (Antalya, Turkey). *Turkish Journal of Zoology*, ***41***, 476-486. DOI: 10.3906/zoo-1602-10