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Original Article

Evaluate the current status of fish species in the Tigris River between Al-Qurna and Al-Azayer cities in Southeastern Iraq

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Abstract: The Tigris River suffers from many problems in water quality due to human interference, climate change, and different discharges. This study aimed to investigate changes in fish assemblage composition and population structure in the Tigris River southeast of Iraq from August 2022 to July 2023. A total of 4343 individuals and 25 species were collected, including four marine species. The total count of native species was 12, exhibiting variation from eight species in June to eleven in August, November, December, February, April, and May. Alien species emerged during nine of the study months, ranging from five species in April to eleven species in June and July. Marine species were present in varying numbers, ranging from two species in December to four species in September, October, January, April, May, and June. Significant differences were found in the number of species among the study stations during different months. The fish species were categorized into three groups: common, seasonal, and occasional species, representing percentages of 72, 24, and 4%, respectively. Among them, *Oreochromis aureus*, *Carassius gibelio*, and *Panaliza abu* constituted 18.35, 16.97, and 10.82% of the total, contributing to 46.143% of the overall species count according to the dominance index (D3). Based on the results, factors such as dissolved oxygen, turbidity, and water salinity had the most positive effect on fish population and biodiversity, and nitrate, phosphate, and total dissolved solids had the most negative effect. In conclusion, the fish assemblage of the Tigris River was relatively similar to that of the downstream Euphrates River, but varied in terms of species number, with the appearance of marine species in this study.

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Introduction

Fish surveys are essential for providing a detailed picture of the nature and makeup of fish stocks, as well as abiotic and biotic variables, including interactions between species such as competition, predation, and the control of fish population dynamics (Zarei Darki and Krakhmalnyi, 2019). Fish populations have long been used as ecological indicators to assess water quality in various spatial and temporal variations of water bodies (Jiang et al., 2021) and to understand the dialectical correlation between the quality and nature of fish assemblages and water quality (Huang et al., 2019). The amount of change in riverine fish populations depends on various spatial parameters, as well as the initial resemblance in the fish population structure before anthropogenic alterations.

Understanding the impacts of variations in accumulation on fish assemblages is also related to the extent of habitats (Sattari et al., 2018; Forouhar Vajargah et al., 2020). Natural variables (climate, physiography, soils, and geology) and anthropogenic activities strongly influence riverine ecosystems by impacting hydrological conditions, pollutant inflow, water quality, habitat characteristics, and biotic communities (Schulze, 2004; Morid et al., 2016; Chakraborty, 2021; Makki et al., 2023). In addition, anthropogenic activities (channelization, damming, and wastewater discharges) can have direct structural

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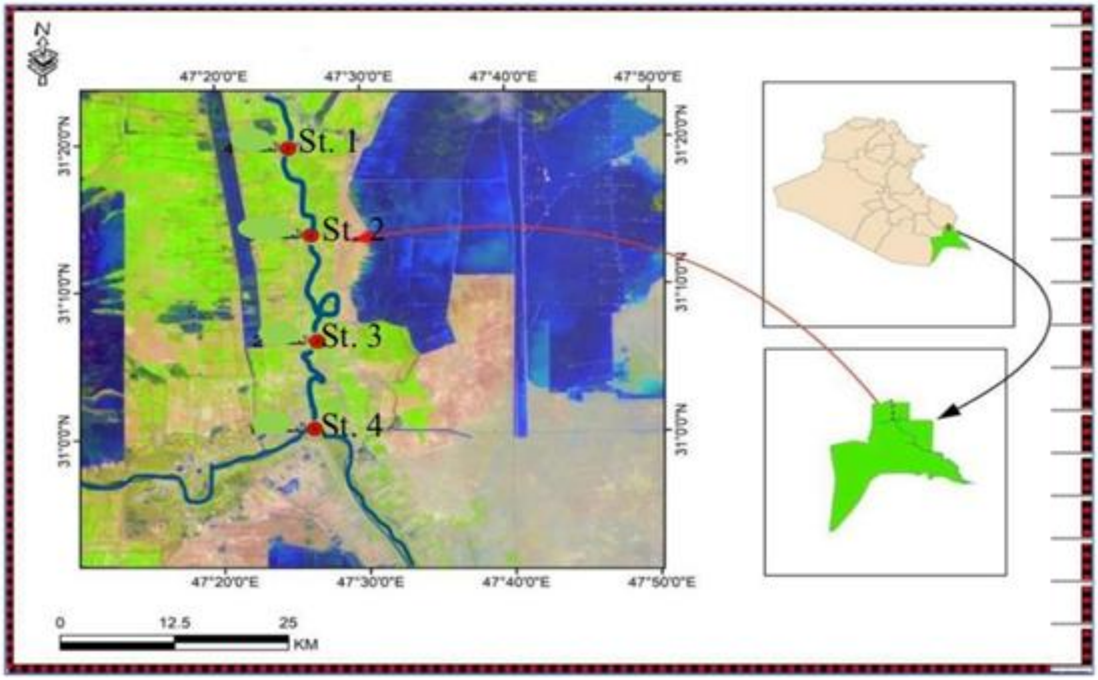

Figure 1. The map and the sampling stations of the study area.

and functional impacts on river ecosystems, impairing ecosystem services (Lopez-Lopez and Sedeno-Díaz, 2015; Fathi and Ahmadifard, 2019; Mamun et al., 2022) and rendering them the most vulnerable ecosystems on the planet. Healthy rivers are essential ecosystems that provide crucial socioeconomic and ecological services, supporting rich species diversity, human benefits, and social development (Pradhan et al., 2021; Mamun and An, 2022).

The waters of the Tigris River experience significant fluctuations in water quality due to various discharges, including agricultural, industrial, and domestic water, as they pass through different cities, in addition to the influence of Lake Tharthar and the Diyala River (Hassan et al., 2013). The discharge of the Tigris River in the past was at a rate of 1,207 m^3/s from 1931 to 1960, and decreased to 522 m^3/s after 2005 (Al-Jawadi et al., 2023).

Several studies have been conducted in Iraq's inland waters to examine the environmental and biological effects on fish populations. Abdullah (2017) investigated the impact of the physicochemical environment on fish diversity and populations in the Tigris River, documenting 27 fish species across 25 genera and 12 families, with a total of 9,400 individual fish collected. Al-Helli et al. (2019) reported on the structure of fish assemblages in the Euphrates River at Al-Samawa city, southern Iraq, finding a total of 4260 fish specimens belonging to 24 species and 10 families, 17 of which are native, while seven are alien species. Additionally, Al-Zaidy (2021) investigated the water quality and conservation status of the local fish fauna in the main outfall drain of Al-Diwaniya City, revealing that the river supports 15 fish species across seven families. Abdullah et al. (2022) studied the fish community, diversity, and status of the Euphrates River in Iraq's Basrah Province, specifically between Medina and Qurna, documenting a total of 7387 fish belonging to 12 families, 21 genera, and 22 species.

This study aimed to highlight the role of rivers in providing estimated diversity and abundance, as well as in the evolution of fish communities. It achieved this by describing habitat characteristics, classifying species occurrence, and recognizing environmental factors that impact the distribution and abundance of fish in the study area, using abundance and fish biodiversity indices over time.

Materials and Methods

Description of the area: The Tigris River is one of the longest rivers in Southeast Asia, spanning a length

Table 1. Sampling stations and their coordinates on the Tigris River.

Stations	Name of station	Latitude (N)	Longitude (E)
1	Al-Azayer city	31.2570	47.43210
2	Al-Sakhrija village	31.1651	47.43138
3	Nakhlate village	31.0913	47.42750
4	Al- Qurna city	31.0210	47.43760

Table 2. Measured water quality parameters.

variables	Unite	method
Dissolved oxygen (DO)	mg/L	Welch (1964)
Total hardness (TH)	mg/L	Lind (1979)
Calcium (Ca^{+2})	mg/L	Lind (1979)
Magnesium (Mg^{+2})	mg/L	Lind (1979)
Nitrate (NO_3)	mg/L	Parson et al. (1984)
Phosphate (PO_4)	mg/L	Murphy and Riley (1962)
Biological oxygen demand (BOD5)	mg/L	APHA (2005)
Alkalinity	mg/L	APHA (2005)
Chloride (Cl^{-1})	mg/L	APHA (2005)

of 1,800 km and encompassing a basin that covers 221,000 km², intersecting four provinces in Iraq (56.1%). It undergoes a transformative journey as reported by UN-ESCWA and BGR (2013). The present study was conducted in the southeastern part of the Tigris River from August 2022 to July 2023. The study area was meticulously delineated, covering the geographical coordinates of Station One (31.2570 N, 47.43210 E) to Station Four (31.0210 N, 47.43760 E). The study area included four stations (Table 1; Fig. 1).

Field sampling: Water samples were collected monthly from four monitoring stations in the Tigris River from August 2022 to July 2023. The samples were collected monthly from the stations using clean polyethylene bottles. The following variables were measured in situ: air and water temperature (℃), potential hydrogen ion concentration (pH), salinity (Sal), total dissolved solids (TDS), and electric conductivity (EC) were recorded using the YSI 556 MPS model 2005. The resulting measurement was expressed in grams per liter (g/l), milligrams per liter (mg/L), and micro-Siemens per centimeter (µS/cm), respectively. The equipment was rigorously calibrated before each field, ensuring the reliability of the measurements obtained. The water's turbidity was measured using a HANNA HI-93703 (Germany), which was determined in Nephelometric Turbidity Units (NTU). The other recorded variables are listed in Table 2.

Several fishing methods were employed to collect fish, including electrofishing using a generator engine (providing 300-400 V, 10A) and gill nets (160-200 m with a 6.4 mm mesh size). Moreover, the adoption of commercial fishing samples was to investigate the types and numbers of fish caught by fishermen. Fish species were identified according to Carpenter (1997) for marine fishes and Coad (2010), Eschemyer (2017), Al-Faisal (2020), Esmaeili et al. (2016), Eagderi et al. (2022), Çiçek et al. (2022, 2023a, b) for freshwater fishes.

The analysis of fish assemblage in the three stations were carried out by the following methods and indices ofrelative abundance (Odum, 1970), occurrence (Tyler, 1971), Diversity (Shannon and Weaver, 1949), evenness (Pielou, 1977), richness index (Margalef, 1968), and dominance (D3) (Kwak and Peterson, 2007), as well as rating of ecological index levels based on Jørgensen et al. (2005).

Canonical Correspondence Analysis (CCA) is a multivariate statistical technique used to analyze the relationships between species abundance and environmental variables. In the context of fish ecology, CCA can be used to assess the relationships between fish populations, environmental factors, and study months (Ter Braak, 1986). All statistical analyses were performed using SPSS (version 20).

Results

Physicochemical environment: The values of the physicochemical parameters are shown in Figure 2. Water temperatures ranged from 19°C in January to 33.88°C in July, with a mean temperature of 26.93±4.78°C in July with a mean value of 26.93±4.78°C. DO varied from 6.98 mg/L in August to 8.53 mg/L in December, with an average value of 7.85±0.44 mg/L. The pH values fluctuated from 7.2 in August to 8.15 in January, with an annual mean of 7.71±0.26. For TDS, the minimum value was 747.75 mg/L in September, while the maximum value was recorded at 1668.50 mg/L in July, with an average of 1162.46±345.08 mg/L. Total hardness (TH) ranged from 621 mg/L in December to 816.25 mg/L in July, with an annual mean of 711.71±66.32 mg/L.

The turbidity values ranged from 50.50 NTU in March to 92.38 NTU in August, with an average of 67.57±12.48 NTU. EC exhibited the lowest value of 1462.5 μc/cm in February and the highest value (1795 μc/cm) in August, with an average of 1606.45±102.72 μS/cm. The values of total alkalinity varied from 85.5 mg/L in January to 152 mg/L in July, with a mean of 111.41±24.17 mg/L. Calcium (Ca^{+2}) values ranged from 150.5 mg/L in December to 178.5 mg/L in July, with an annual mean of 164.77±8.78 mg/L. The observed values for nitrate (NO_3) ranged from 4.87 mg/L in August to 31.58 mg/L in July, with an annual mean of 12.64±8.44 mg/L. Phosphate (PO_4) values fluctuated from 1.24 mg/l in August to 5.84 mg/L in June, with an average of 3.225±1.38 mg/L. The stations displayed a salinity range of 0.94 g/L in February to 1.15 g/L in August, with a mean value of 1.03±0.06 g/L. The magnesium (Mg^{+2}) levels varied from 55.55 mg/L in September to 90.45 mg/L in February, with an average of 73.01±13.22 mg/L across the study stations. Chloride (Cl^{-1}) displayed an annual mean of 187.81±13.48 mg/L, with the lowest record of 162.5 mg/L in March and the highest record of 210.75 mg/L in August. The levels of Biological Oxygen Demand (BOD_5) ranged from 0.70 mg/L in February to 1.63 mg/L in August, with an average of 1.14±0.34 mg/L.

Fish community: Throughout the study period, a comprehensive assessment was conducted at four stations. A total of 4,343 individuals were identified, representing 25 species, with four of them being marine species. These species were categorized into 25 different genera and belonged to 14 families. The family Cyprinidae demonstrated remarkable dominance in terms of the number of species recorded, encompassing a total of six species, including *Carassius gibelio*, *Cyprinus carpio*, *Carasobarbus luteus*, *Luciobarbus xanthopterus*, *Mesopotamichthys sharpeyi*, and *Garra rufa.* These six species accounted for 24.13% of the overall numerical proportions. Furthermore, these cyprinid species were distributed among six different genera. Notably, the Cyprinidae family accounted for 23.8% of the total weight of all collected species.

Additionally, the Cichlidae and Luciscidae families each featured three species: *Oreochromis aureus, O. niloticus, Coptodon zillii, Leuciscus vorax, Alburnus mossulensis,* and *Acanthobrama marmid* demonstrated relative and weight abundances of 32.56, 12.71, 27.432, and 8.783%, respectively. The families of Xenocyprididae and Mugilidae, comprising two species each, are formed from *Hemiculter leucisculus*, *Ctenopharyngodon idella*, *Planiliza abu*, and *P. subviridis*, which serve as the relay for each family. The remaining families, Clupeidae, Engraulidae, Siluridae, Poeciliidae, Cyprinodontidae, Heteropneustidae, Bagridae, and Mastacembelidae, each consisted of a single species (Table 3).

Species abundance and distribution: Table 4 shows the monthly variations in the relative representation of fish species across all stations in the study area. Of the 25 species collected, *O. aureus* revealed significant dominance, reaching its highest abundance at 18.35%. It ranged from 15.28% in February to 27.08% in October. *Carassius gibelio* was classified second with

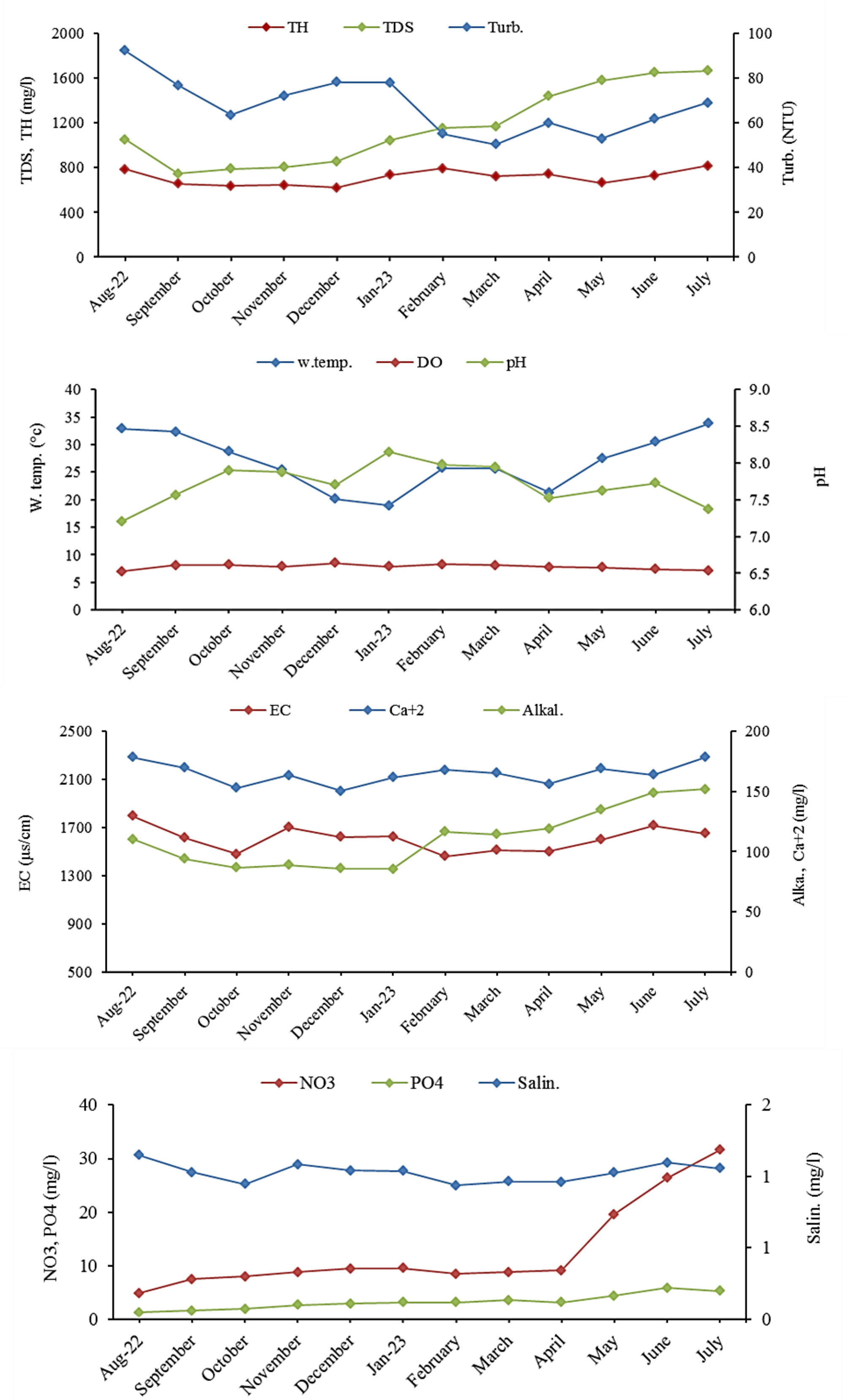

Figure 2. The values of water quality parameters in the studied stations along the Tigris River.

a contribution of 16.97%. Its relative abundance varied between 11.53% in October and 24.04% in June. *Panaliza abu* occupied the third position, accounting for 10.82% of the catch. Its abundance

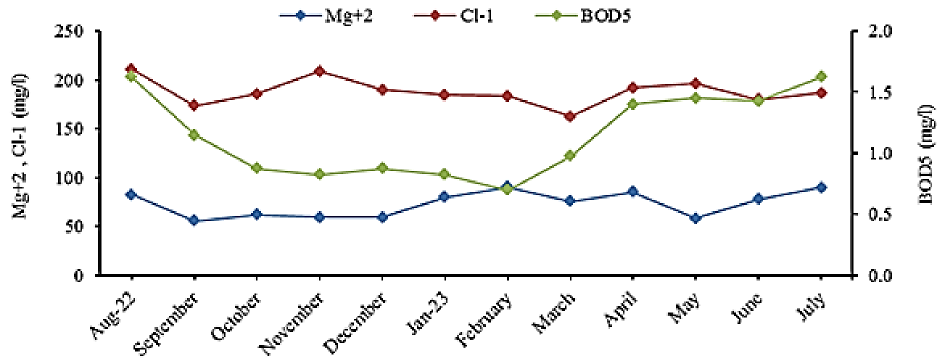

Figure 2. To be continued.

Table 3. Fish families, species, and environments in the southeastern part of the Tigris River from August 2022 to July 2023.

Family	Relative abundance %	Weight abundance %	Species	Habitat
Cyprinidae	24.130	23.8	*Carassius gibelio* + *Cyprinus carpio* + *Carasobarbus luteus* * *Luciobarbus xanthopterus* * *Mesopotamichthys sharpeyi* * *Garra rufa**	F F F F F F
Cichlidae	32.56	27.432	*Oreochromis aureus* + *Oreochromis niloticus* + *Coptodon zillii* +	F F F
Leuciscidae	12.71	8.783	*Leuciscus vorax* * *Alburnus sellal* * *Acanthobrama marmid**	F F F
Xenocyprididae	3.155	2.561	*Hemiculter leucisculus* + *Ctenopharyngodon idella* +	F F
Mugilidae	11.14	6.191	*Planiliza abu** *Planiliza subviridis*	F M
Clupeidae	3.5	3.241	*Tenualosa ilisha*	M
Sparidae	0.332	0.365	*Acanthopagrus arabicus*	M
Engraulidae	5.319	2.096	*Thryssa whiteheadi*	M
Siluridae	2.095	17.1	*Silurus triostegus**	F
Poeciliidae	0.184	0.052	*Gambuzia holbrooki* +	F
Cyprinodontidae	0.184	0.073	*Aphanius dispar* *	F
Heteropneuetidae	0.05	0.01	*Heteropneustes fossilis* +	F
Bagridae	2.92	2.39	*Mystus pelusius**	F
Mastacembelidae	1.73	5.50	*Mastacembelus mastacembelus**	F

* = Native species, + = Alien species, F = Fresh water species, and M = Marine water species.

ranged from 5.78% in August to 16.72% in January. *Oreochromis niloticus* appeared in the fourth position, representing 7.53% of the catch. Its presence was recorded at 2.89% in August and at 12.33% in October. The following was the species *C. zillii*, with a total richness of 6.68%, exhibiting variations from 2.89% in August to 11.85% in June.

Thryssa whiteheadi followed with a total percentage of 5.32, ranging from 0.94% in July to 9.29% in September. *Alburnus sellal* followed with a rate of 4.90%, reaching its lowest value of 2.14% in October and its highest value of 8.13% in July. The

Table 2. The monthly variations in the relative abundances collected at all stations in the Tigris River from August 2022 to July 2023.

Months	Aug.2022	Sep.	Oct.	Nov.	Dec.	Jan. 2023	Feb.	Mar.	Apr.	May	June	July	Total
Species	%	%	%	%	%	%	%	%	%	%	%	%	%
O. aureus	17.87	15.77	27.08	18.72	15.77	17.63	15.28	22.59	17.67	16.01	19.51	20.31	18.35
C. gibelio	17.15	17.93	11.53	14.45	18.46	17.93	13.89	14.44	15.00	21.78	24.04	20.31	16.97
P. abu	5.78	10.80	13.94	6.64	15.10	16.72	13.89	11.48	14.33	8.66	9.41	10.63	10.82
O. niloticus	2.89	3.89	12.33	8.29	11.74	9.12	8.68	8.52	6.67	8.66	6.62	8.44	7.53
C. zillii	2.89	5.62	10.72	4.50	4.36	4.56	7.99	7.78	7.67	6.82	11.85	10.63	6.68
T. whiteheadi	8.48	9.29	3.49	3.32	5.03	4.56	6.60	4.81	5.00	6.82	2.79	0.94	5.32
A. mossulensis	5.23	5.62	2.14	4.27	5.37	7.29	4.17	3.70	6.00	2.62	5.57	8.13	4.90
L. vorax	5.42	3.89	0.54	11.85	6.04	3.65	6.60	4.44	5.00	1.84	1.05	1.25	4.37
T. ilisha	9.57	4.10	1.07	1.66	0.67	0.91	2.43	2.96	3.33	6.30	2.44	2.50	3.50
A. marmid	5.60	3.89	2.14	2.37	3.36	3.34	3.13	2.96	5.00	3.41	2.09	3.13	3.43
C. luteus	3.43	3.89	1.34	8.29	3.36	2.13	3.82	2.96	1.33	3.67	3.14	1.25	3.32
M. pelusius	4.51	1.08	4.29	0.71	3.02	2.43	2.78	2.59	2.33	6.56	1.74	2.81	2.92
H. leucisculus	3.25	7.13	1.34	6.16	1.68	1.52	1.74	2.22	2.33	1.05	1.39	1.56	2.83
S. triostegus	2.17	1.51	3.49	1.42	3.69	2.13	2.78	2.59	2.67	1.31	0.70	1.56	2.10
C. carpio	2.17	2.59	2.14	2.37	2.35	1.82	0.69	2.22	1.67	1.05	2.79	1.88	1.98
M. mastacembelus	0.90	1.51	2.14	1.66	3.02	1.82	2.08	3.33	1.67	1.31	1.05	1.56	1.73
M. sharpeyi	2.53	2.16	0.27	1.18	1.01	0.91	1.74	0.37	1.33	0.79	1.05	0.63	1.24
L. xanthopterus	0.54	0.22	0.27	0.95	0.67		0.35		0.33	0.52	0.70	0.31	0.41
P. subviridis		0.65	1.07	0.24		0.30	0.69		0.33	0.26	0.35		0.32
A. arabicus	0.36	0.43	0.27			0.30		1.11	0.33	0.79		0.31	0.32
C. idella				0.47	0.34	0.30		0.74		0.52	1.05	0.94	0.32
G.rufa	0.18			0.95	0.34		0.35			0.26		0.31	0.21
G. holbrooki	0.18	0.43		0.47			0.35			0.26	0.35		0.18
A.dispar		0.22				0.61		0.37		0.26	0.35	0.63	0.18
H. foosilis				0.47									0.05

percentage of *L. vorax* fish was recorded at 4.37, varying from 0.54% in October to 11.85% in November. *Tenualosa ilisha* followed with a total ratio of 3.50%, fluctuating between 0.67% in December and 9.57% in August. *Acanthobrama marmid* exhibited a total abundance of 3.43%, with a range varying from 2.09% in June to 5.60% in August. *Carasobarbus luteus* represented 3.32% of the catch, recorded at 1.25% in July, and increased to 8.29% in November.

Mystus pelusius showed 2.92% of the total catch, ranging from 0.71% in November to 6.56% in May, and *H. leucisculus*, with a total catch of 2.83%, ranged from 1.05% in May to 7.13% in September. After that, *S. triostegus* constituted 2.10% of the total catch, with variations from 0.70% in June to 3.69% in December. *Cyprinus carpio* was signified by a total of 1.98%, reaching from 0.69% in February to 2.79% in June. *Mastacembelus mastacembelus* had a total abundance of 1.73%, ranging from 0.90% in August to 3.33% in March.

Low percentages were recorded for species of *M. sharpeyi, L. xanthopterus, P. subviridis, A. arabicus, C. idella, G. rufa, G. holbrooki, A. dispar,* and *H. fossilis,* with total abundances of 1.24, 0.41, 0.32, 0.32, 0.32, 0.21, 0.18, 0.18, and 0.05%, respectively, of the total abundance. Significant variations ($P<0.05$, F = 13.263, Sig. = 0.013) were recorded in the percentage of fish species and the number of individuals throughout the study period.

The total number of native species included 12 species: *C. luteus, L. xanthopterus, M. sharpeyi, G.rufa, L. vorax, A. sellal, A. marmid, M. pelusius, M. mastacembelus, P. abu, S. triostegus,* and *A. dispar*. The number of species varied between eight in June and 11 in August, November, December, February, April, and May. The alien species consisted of *C. gibelio, C. carpio, O. aureus, O. niloticus, C. zillii, H. leucisculus, C. idella, G. holbrooki,* and *H. fossilis*, ranging from five species in April to 11 species in June and July. The marine species consisted of four species, which were observed at the fourth station. The number of marine species comprised *P. subviridis*, *T. ilisha*, *A. arabicus*, and *T. whiteheadi*, ranging between two species in December and four species in September, October, January, April, and May. Significant differences ($P<0.05$, F = 88.291, Sig. = 0.000) were observed in the number of species and individuals across the study stations during the

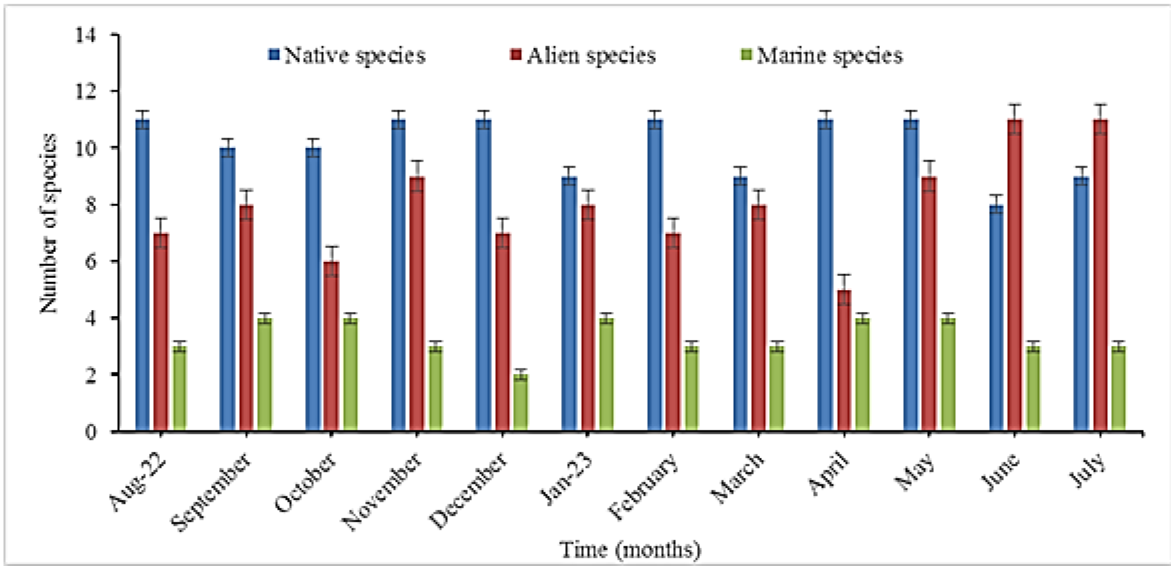

Figure 3. Monthly variations in the presence of fish species (native, alien, marine) in the study area from August 2022 to July 2023.

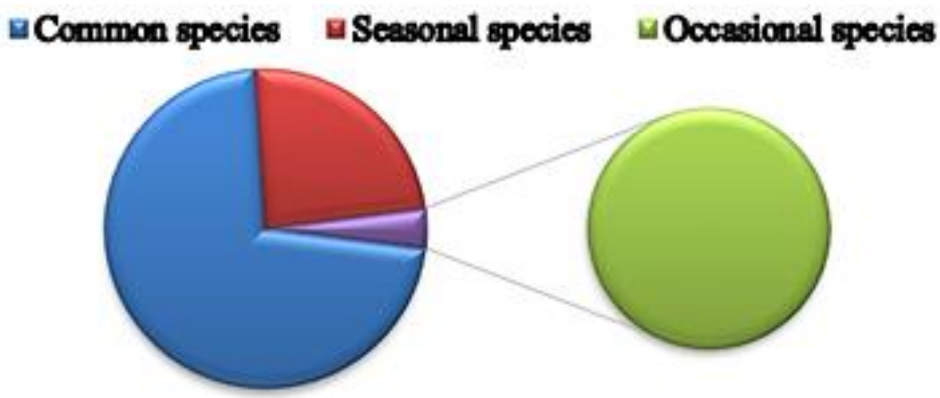

Figure 4. The percentage distribution of fish species (common, seasonal, and occasional) throughout the study period.

different months (Fig. 3).

Occurrence of fish species: Eighteen species represent the common species, including *O. aureus, C. gibelio, P. abu, O. niloticus, C. zillii, T. whiteheadi, A. mossulensis, L. vorax, T. ilisha, A. marmid, C. luteus, M. pelusius, H. leucisculus, S. triostegus, C. carpio, M. mastacembelus, M. sharpeyi* and *L. xanthopterus*, consist of 72% of the total catch (Fig. 4). Six species compose the seasonal species included *P. subviridis, A. arabicus, C. idella, G.rufa, G. holbrooki* and *A. dispar* accounting for 24% of the total catch. One of the occasional species, *H. fossilis*, contributes to 4% of the total catch.

Ecological indices: The rate value of Shannon and Weaver diversity index (H), Evenness (J), and Margalef richness (D) were calculated according to season in the study area (Fig. 5). The mean value and standard deviations of Shannon and Weaver in all stations were 2.28±0.20, 0.83±0.06, and 3.26±0.35, respectively. The lowest Shannon diversity index (2.23) was recorded in Summer, and the highest (2.35) was in Autumn. The evenness values varied from 0.78 in Summer to 0.87 in autumn. Lowest Margalef richness (D) (3.01) was in Spring, and the highest (3.56) was in Summer. Three fish species, *O. aureus*, *C. gibelio*, and *P. abu*, accounted for 18.35, 16.97, and 10.82%, respectively, and comprised 46.143% of the total number of species according to the dominance index (D3).

Relationship between abiotic characteristics and fish distribution: The results of the CCA are illustrated in Figure 6 and explained in detail in the attached table. In CCA, three distinct fish groups were identified by the selected order. Specie Sp1 exhibited

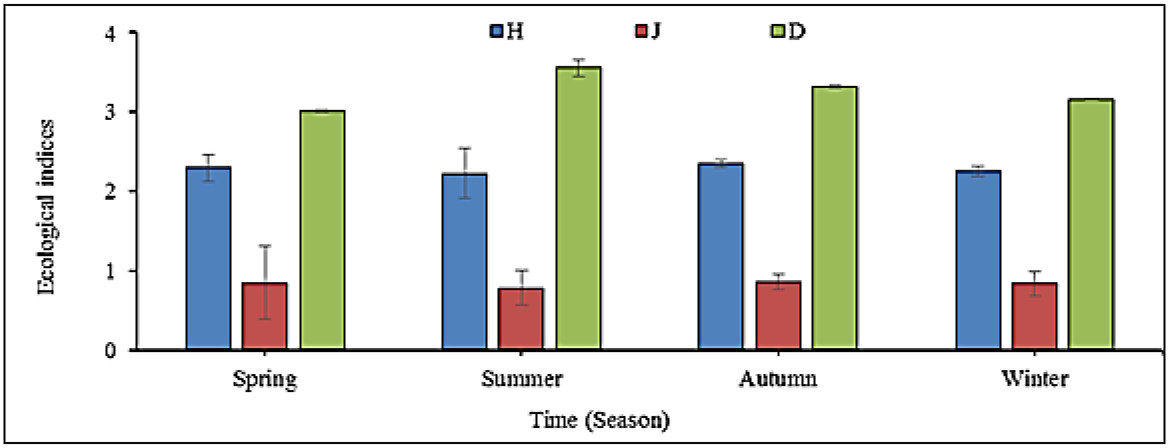

Figure 5. Comparison of changes in river ecological indices during the study period.

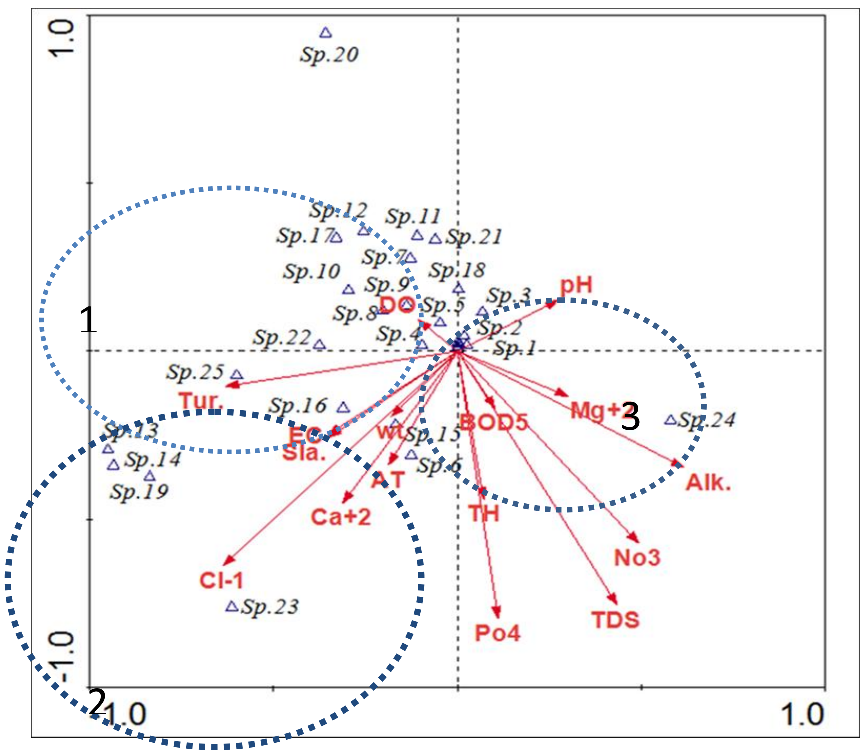

Figure 5. The CCA method derived the relationship between ecological factors and the distribution of the fish community. Sp1. (*Planiliza abu*), SP2. (*Coptodon zillii*), Sp3. (*Carassius gibelio*), Sp4. (*Alburnus sellal*), SP5. (*Oreochromis aureus*), Sp6. (*Oreochromis niloticus*), Sp7. (*Carasobarbus luteus*), Sp8. (*Cyprinus carpio).* SP9. (*Silurus triostegus*), Sp10. (*Acanthobrama marmid*), Sp11. (*Leuciscus vorax*), Sp12. (*Hemiculter leucisculus*), Sp13. (*Planiliza subviridis*), Sp14. (*Tenualosa Ilisha*), Sp. 15. (*Mystus pelusius*), Sp.16 (*Luciobarbus xanthopterus*), Sp.17. (*Gambusia holbrooki*), Sp. 18. (*Mastacembelus mastacembelus),* Sp.19. (*Acanthopagrus arabicus),* Sp.20. (*Heteropneustes foosilis).* Sp. 21. (*Mesopotamichthys sharpeyi*), Sp.22. (*Thryssa whiteheadi*), Sp.23. (*Aphanius dispar*), Sp. 24. (*Ctenopharyngodon idella*), and Sp. 25. (*Garra rufa)*

the highest abundance across all four stations. It displayed a positive correlation with pH and DO, with correlation coefficients of r = 0.298 and r = 0.422, respectively. Conversely, a negative correlation was observed between the Sp1 and factors such as TDS, EC, salinity, and BOD, with correlation coefficients of r = -0.418, r = -0.393, r = -0.611, and r = -0.395, respectively. On the other hand, Specie Sp9 demonstrated a positive correlation with DO and turbidity, with correlation coefficients of (r = 0.321 and r = 0.411), respectively. These correlations highlighted the specific associations between these abiotic factors and the distribution patterns of the mentioned fish species within the aquatic environment. Similarly, we observed a correlation with other species.

Discussions

Physicochemical environment: Ecological factors influence the structuring, distribution, and abundance of fish assemblages in river habitats (Leitao et al., 2018). In shallow waters, elevated temperatures expose fish to thermal stress, prompting them to migrate towards deeper regions in riverine habitats to evade this stress (Hendy et al., 2020). Temperature variations during the months, in conjunction with DO and salinity, may strongly contribute to the composition, prevailing differences, and distribution of the fish assemblage in river environments (Abdullah et al., 2022). DO, pH, and BOD5 in the present study were within the range of the WHO and Iraqi standards for protecting general water resources (Standard Specification, 2009) and the United Nations (2010), and agreed with previous studies on Iraqi inland waters (Al-Ansari, 2013).

This study examines the relationship between water salinity, TDS, TH, and EC in freshwater bodies of inland Iraq, encompassing both inorganic and organic dissolved substances in water, including minerals, salts, metals, and various compounds. Additionally, the increase may be attributed to the effects of domestic effluent discharges, industrial runoff with high suspended matter content, and lower water levels (WHO, 2011). Our findings align with those of Majeed et al. (2022) and Abdullah et al. (2019). The turbidity levels were found to be greater. The buildup of human waste in the river, together with the rise in rainfall and increasing water levels, might be the cause of this (Hassan and Mahmood, 2018). Al-Kinani and Al-Azawi (2022) noted that agricultural waste may be actively contributing to the increase in turbidity. The results showed that the highest turbidity values exceeded the World Health Organization's recommended limits of 0 to 5 nanometers. Alkalinity and bicarbonate alkalinity were within this range according to our research (Rice et al., 2012). The mineral composition of the soil and watershed, together with their exposure to treated sewage and industrial waste, are two main factors that contributed to the elevated levels of $Ca+^{2}$ and Mg^{+2} in the studied region.

Nitrate and phosphate concentrations in untreated water usually meet or exceed both Iraqi and World Health Organization guidelines. The NO_3 and PO_4 levels were found to be within this range in our investigation, which is consistent with earlier research (Issa, 2018; Rzaij et al., 2020). The investigation revealed that the average BOD5 measurements at the research stations fell within the range specified by the Standard Specification (2009) and the World Health Organization. Obaid (2021) and Al-Obaidy et al. (2022) tested water quality on Iraqi surfaces, and their findings align with the current findings on freshwater in Iraq. Anion chloride is ubiquitous in both potable water and wastewater. Chloride levels were within the safe range, averaging 250 mg/L. The findings of our research align with those of Al-Ani et al. (2014).

Fish community: The ecological and economic importance of fish is significant due to their status as the largest and most diverse group of vertebrates. The cyprinid family was found to be relatively abundant among the collected species. Their predominance in the captures reported across several studies in Iraq's inland waterways is shown by their significance. In a detailed analysis of the Al-Huwaizah marsh in southern Iraq, the assemblage structure was shown to be dominated by nine different species of Cyprinidae (Al-Thahaibawi et al., 2019). The predominance of the Cyprinidae family in the Al-Diwaniya and Saghez River fish assemblage structure was also confirmed by Mohamed and Al-Jubouri (2017) and Fathi Ahmadifard (2019).

Species abundance and distribution: The results show monthly variations in the relative abundance of fish species at all study sites. The 25 species vary somewhat from previous works in the Tigris River. The research by Abdullah (2017) included the collection of 27 different types of fish. Notable studies on fish composition in the Euphrates River (Al-Helli et al., 2019) and invasive alien species in the Al-Dalmaj protected area (Salim et al., 2021) demonstrate that inland surface waters can be home to both exotic and invasive fish species. During periods of primary production booms, native species often migrate into the intertidal zone to access food sources. The results align with those of an earlier study (Abdullah, 2023). Twelve major native species were found in the research region, according to the data. Mohamed and Abood (2017) and Abdullah et al. (2022) documented the abundance of these species in southern Iraq. In contrast, alien species can withstand a wide range of environmental stresses and consume a diverse array of foods. In the present study, we reported nine exotic species, unlike previous studies that reported a lower number of exotic fish (Al-Faisal et al., 2014). Four marine species were recorded downstream at the fourth location of the Tigris River, comprising four species. This finding aligns with the study conducted by Mohamed et al. (2015), although the specific marine species were different.

Occurrence of fish species: Tyler (1971) categorized the fish assemblage into three distinct groups: common, seasonal, and occasional species. The fish species of *O. aureus, C. gibelio, P. abu, O. niloticus, C. zillii, T. whiteheadi, A. mossulensis, L. vorax, T. ilisha, A. marmid, C. luteus, M. pelusius, H. leucisculus, S. triostegus, C. carpio, M. mastacembelus, M. sharpeyi,* and *L. xanthopterus* fall into the common category, as they were consistently collected throughout the 12-month sampling period. Al-Noor et al. (2009) also reported the presence of these species in their study of the fish community in the lower reaches of the Euphrates River at its confluence with the Tigris River. However, they observed some variations in species composition. Furthermore, six species were classified as seasonal (*P. subviridis, A. arabicus, C. idella, G. rufa, G. holbrooki,* and *A. dispar*), and one species, *H. fossilis*, was considered occasional. The presence of these species exhibited monthly variations, differing from the results reported by Hussain et al. (2012).

Ecological indices: Biodiversity indices serve as a singular numeric representation for describing the diversity within a given system (Magurran, 1988). The values of H range from poor to medium, based on the Shannon-Weaver index values (Younis et al., 2010). The evenness index (J) results indicate a range from half-balanced to unbalanced, with a slight increase attributed to the presence of certain marine species in the lower part of the Tigris River (Mohamed et al., 2015). Regarding richness (D) in the fish structure across all locations, as per Jorgensen et al. (2005), it varies between disturbed and semi-complete, consistent with the findings of the current study. The three most abundant fish species, *O. aureus, C. gibelio*, and *P. abu*, dominantly contribute to the ecosystem (D3) in the Tigris River, in alignment with previous research conducted in Iraqi inland waters (Jawad et al., 2021).

Diversity of fish species and ecological variables: This study categorizes fish into three main groups. The first group, which is positively linked to DO, mainly consists of resident fish. In contrast, this group exhibits a negative correlation with salinity, aligning with findings from numerous studies on Iraqi inland waters (AL-Zaidy et al., 2021). The second group, which is positively associated with salinity, mainly includes exotic fish and four species of marine fish, consistent with previous research on Iraqi inland waters by Mohamed et al. (2015) and Abood (2018). The third group comprises three fish species that exhibit a weak positive correlation with pH and DO, consistent with the findings of Hossain et al. (2012).

Conclusion

The structure of the fish community varies due to the high proportion of alien species documented in this study. The fish assemblage of the Tigris River was relatively similar to that of the downstream Euphrates River, but varied in the number of species, with the appearance of marine species in this study.

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