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Use of Fish Assemblage as Environmental Indicators for the Shatt Al-Arab, Dora Area, Basrah, Iraq

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ABSTRACT

Environmental indicators and fish species composition at the Shatt al-Arab, Dora Station were investigated using four types of fishing gear, through which a total of 17,789 fish specimens were collected. These specimens represented 15 orders, 35 families, 50 genera, and 59 species. All species belong to the class Osteichthyes, except for four species classified under Chondrichthyes. The ichthyofaunal composition included 51 marine species (86.44%) and 8 freshwater species (13.56%). Based on their occurrence, species were categorized into 12 common, 10 seasonal, and 36 occasional species. The Mugilidae family was the most dominant, accounting for 27.74% of the total catch, followed by the Engraulidae family at 20.69%. Among the individual species, *Planiliza klunzingeri* ranked first in relative abundance (21.24%), followed by *Thryssa whiteheadi* (18.05%). The highest numerical abundance was recorded in September with 2,587 individuals, while the lowest occurred in January with 364 individuals. The Shannon-Wiener diversity index peaked at 2.69 in September and dropped to 1.69 in February. The evenness index reached its highest value in November (0.79) and the lowest in March (0.59). Species richness (Margalef index) was at its highest in September (4.33) and lowest in January (2.03). The dominance index was recorded with the highest value in January (0.77) and the lowest in September (0.44). Among the environmental factors studied, salinity and water temperature were the most influential, accounting for 47.69% of the total effect on fish abundance and diversity. These two parameters significantly shaped the observed environmental indicators, with strong correlations between their fluctuations and the biological responses of fish communities.

INTRODUCTION

Freshwater ecosystems are deeply intertwined with human society, functioning as organizational hubs within nature and providing a wide array of cultural, ecological, and economic services. They support high levels of biodiversity and play a crucial role in meeting the growing water demands of human populations while maintaining environmental integrity. However, this very importance has rendered freshwater habitats among the most endangered ecosystems globally **(Jenkins, 2003; Apostolaki *et al.*, 2020)**.

Among the major threats to freshwater biodiversity are invasive fish species, which are increasingly recognized as significant contributors to the extinction of native species. Their impact is compounded by habitat loss and fragmentation, altered hydrology, climate change, overexploitation, and pollution **(Dudgeon *et al.*, 2006)**. Despite widespread recognition of the physical, chemical, and biological degradation of aquatic environments, the loss of biodiversity in these systems has received relatively little attention. This decline has far-reaching consequences, including the spread of waterborne diseases, collapse of fisheries, and deterioration of water quality **(Havel *et al.*, 2015; Pinna *et al.*, 2023)**.

Fish community composition studies are vital for understanding ecological interactions among species, the effects of environmental changes, and the impacts of human activities **(Garlsoon *et al.*, 2000)**. Fish surveys provide essential data on fish stock composition and distribution, enabling assessments of species richness, population dynamics, and ecological health **(Korsbrekke *et al.*, 2001)**. Catch data across various locations offer insights into both commercial and non-commercial species, including estimates of total length, age, growth rates, and mortality **(Pennington *et al.*, 2002)**.

However, inland fish diversity faces significant threats due to poor management, including overfishing and the use of illegal fishing methods. These practices contribute to a collapse in both species numbers and diversity, driven by unsustainable fishing pressure **(Pauly *et al.*, 2002)**. As noted by **Ibarra *et al.* (2005)**, freshwater fish communities are influenced by a combination of physical and chemical environmental factors, which in turn shape vital biological interactions among species.

The Shatt al-Arab River is one of Iraq’s most important rivers due to its ecological, economic, and social value. It serves as a critical source of surface water for the Basra Governorate, supporting activities such as water supply, fisheries, navigation, and industrial use **(Hussain *et al.*, 1991)**. Flowing into the Arabian Gulf, the river’s estuary represents a highly productive environment, shaped by tidal influences and discharge rates from the Tigris and Euphrates rivers **(Mohamed *et al.*, 2012)**. Unfortunately, the river has been subjected to various forms of pollution, primarily from untreated domestic, industrial, and agricultural discharges **(Moyel, 2010)**.

This study aimed to assess the composition of the fish community in the Shatt al-Arab River, along with associated environmental indicators, by evaluating the extent to which these are influenced by environmental variables using multivariate analyses. Several prior studies have explored fish biodiversity and environmental conditions in this river system, including those by **Yaseen *et al.* (2018)**, **Abdullah *et al.* (2021) Resen *et al.* (2023)** and **Ahmed *et al.* (2024)**.

MATERIALS AND METHODS

1. Description of the study area

Fish samples for this study were collected from the Dora area, located at the coordinates N 30°8'33.77" / E 48°23'32.41", as shown in Fig. (1). Four types of fishing gear were used to ensure comprehensive sampling. These included fixed gill nets measuring 200 meters in length and 2.5 meters in height, with a mesh size of 25 × 25 mm; floating gill nets measuring 200 meters in length and 3.5 meters in height, with a mesh size of 48 × 48 mm; and gill nets 150 meters in length with mesh sizes ranging from 16 × 16 mm to 20 × 20 mm. Additionally, a bottom trawl net with very fine mesh was employed to capture smaller, benthic fish species.

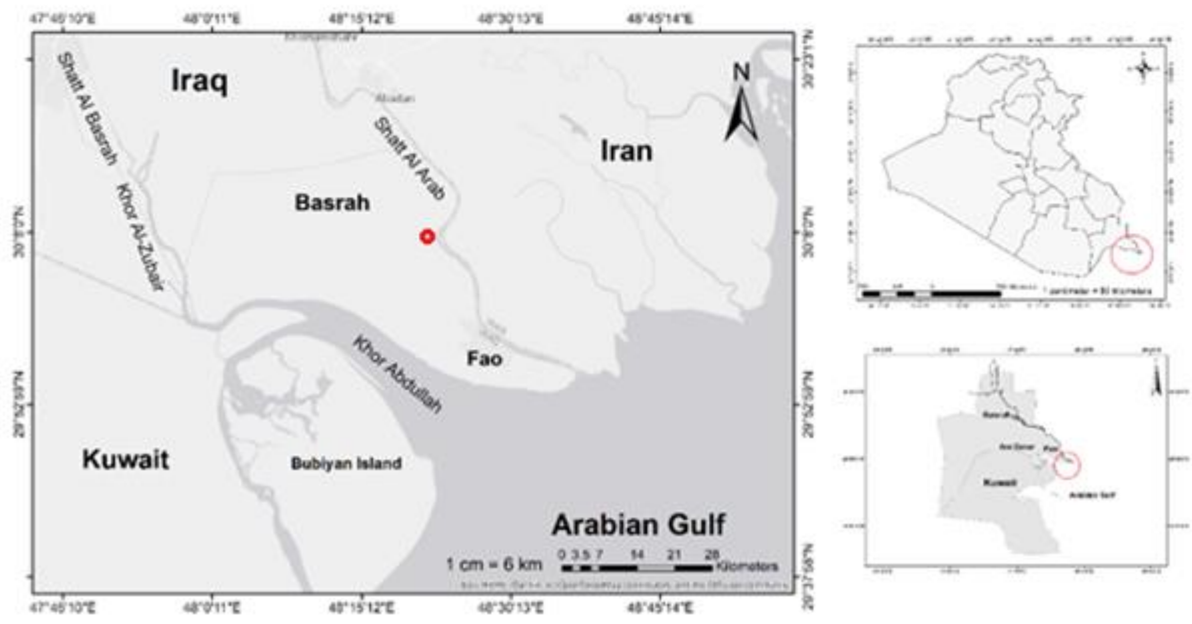

Fig. 1. A map showing the sample collection area

The collected samples were stored in refrigerated plastic containers until brought to the laboratory. Some environmental factors were measured in the field using an American-made (YSI, 556MPS) device, and water turbidity was measured using a German-made (Lovibond) device in NTU units. Dissolved phosphate, nitrate and nitrite were measured in the laboratory based on the methods of **Clesceri *et al*. (1998)**. Fish samples caught during the study were classified according to their species based on categorization of **Carpenter *et al*. (1997)**, **Coad (2010)** and **Fricke *et al*. (2023)**. The families and orders of these species were also determined, and the numbers and weights of individuals for all studied species were recorded.

Fish species were divided into three groups based on their occurrence in the samples according to **Tyler (1971)**.

The following indicators were used to analyze the fish community:

- Relative abundance according to **Krebs (1974)**:

Relative Abundance % = (ni/N) x100. Where: ni = number of individuals of the species in the monthly sample, N = total number of the monthly sample.

- Diversity index (H) according to **Shannon and Weaver (1949)**.

H= -∑ Pi ln Pi. Where: Pi = the ratio of the number of individuals of each species to the total number.

- Evenness index (J) according to **Pielou (1977)**. J = H /ln S, Where: H = diversity index; S = number of species.

- Richness index (D) according to **Margalefe (1968)**. D = S-1/ln N, where: S = number of species; N = total number of individuals in the sample.

- Dominance index (D_3) according to **Kwak and Peterson (2007)**.

To determine the abundance of the three most abundant species $D_3 = [\sum_{i=1}^{3} pi.]$ 100, Since:

Pi = the ratio of the number of individuals of the three most abundant species to the total number.

- Importance Relative Index (IRI) according to **Jutagate *et al*. (2005)**:

%IRI = [(%Wi +%Ni) %Fi / ∑ (%Wi +%Ni) %Fi] 100, Where: %Wi = percentage of the weight of the species in the monthly catch sample. %Ni = percentage of the species in the monthly catch sample. %Fi = percentage of occurrence of the species in all catches.

- Jaccard similarity index according to **Jaccard (1908)**: Ss % =(a/a+b+c) 100; Since: a = the number of species shared by both samples A and B; b = the number of species present in sample A but not present in sample B; c = the number of species present in sample B but not present in sample A.

The statistical program SPSS (version 22.0) was used to analyze the correlation between environmental factors. The program XLSTAT (version 2023) was used to perform principal component analysis and principal component analysis with supplementary variables. Statistica (version 10.0) was employed to measure the percentage similarity between monthly fishing samples.

RESULTS

Description of the fish community structure

During the study period, a total of 17,787 fish were caught. These fish belong to 59 species, 50 genera, 35 families, and 15 orders, most of which are Osteichthyes, except for four species classified as Chondrichthyes. The area comprised 51 marine species and 8 freshwater species. Table (1) presents a description of the fish community composition in the area.

Table 1. Description of the composition of the fish community in the region

Scientific name of Order species	Scientific name of family species	No. of Genus	Habitat	Scientific name
Carcharhiniformes	Carcharhinidae	1	†‡	*Carcharhinus leucas*
	Sphyrnidae	1	†‡	*Sphyrna mokarran*
Rajiformes	Dasyatidae	1	†‡	*Pastinachus sephen*
		1	†‡	*Himantura uarnak*
Clupeiformes	Engraulidae	1	†	*Thryssa mystax*
			†	*Thryssa whiteheadi*
			†	*Thryssa dussumieri*
	Dorosomatidae	1	†	*Nematalosa nasus*
	Dorosomatidae	1	†	*Tenualosa ilisha*
	Dorosomatidae	1	†	*Sardinella albella*
	Dorosomatidae		†	*Sardinella longiceps*
	Chirocentridae	1	†	*Chirocentrus nudus*
	Chirocentridae		†	*Chirocentrus dorab*
	Pristigasteridae	1	†	*Ilisha compierssa*
Gonorynchiformes	Chanidae	1	†	*Chanos chanos*
Cypriniformes	Cyprinidae	1	*	*Carassius auratus*
	Cyprinidae	1	*	*Carasobarbus luteus*
	Cyprinidae	1	*	*Leuciscus vorax*
Siluriformes	Plotosidae	1	†	*Plotosus lineatus*
	Siluridae	1	*	*Silurus triostegus*
	Ariidae	1	†	*Arius thalassinus*
Gobiiformes	Gobiidae	1	†	*Boleophthalmus dussumieri*
		1	†	*Paratrypauchen microcephalus*
		1	†	*Bathygobius fuscus*
Syngnathiformes	Mullidae		†	*Upeneus tragula*
Scombriformes	Scombridae	1	†	*Scomberomorus commerson*
	Trichiuridae	1	†	*Trichiurus lepturus*
		1	†	*Eupleurogrammus glossodon*
		1	†	*Eupleurogrammus muticus*
Carangiformes	Sphyraenidae		†	*Sphyraena obtusata*
	Polynemidae	1	†	*Eleutheronema tetradactylum*
	Soleidae	1	†	*Solea stanalandi*
		1	†	*Brachirus orientalis*
	Cynoglossidae	1	†	*Cynoglossus arel*
	Carangidae	1	†	*Scomberoides commersonnianus*
		1	†	*Alepes djedaba*
		1	†	*Parastromateus niger*
Beloniformes	Belonidae	1	†	*Tylosurus crocodilus*
Cichliformes	Cichlidae	1	*	*Oreochromis aureus*
Cichliformes	Cichlidae	1	*	*Coptodon zillii*
Cichliformes	Cichlidae		*	*Oreochromis niloticus*
Mugiliformes	Mugilidae	1	†	*Planiliza klunzingeri*
			†	*Planiliza subviridis*
			*	*Planiliza abu*

Perciformes	Serranidae	1	†	*Epinephelus areolatus*
	Platycephalidae	1	†	*Platycephalus indicus*
	Synanceiidae	1	†	*Pseudosynanceia melanostigma*
		1	†	*Choridactylus multibarbus*
	Scorpaenidae	1	†	*Pterois miles*
Acanthuriformes	Sillaginidae	1	†	*Sillago sihama*
	Sciaenidae	1	†	*Johnius sina*
			†	*Johnius belangerii*
		1	†	*Otolithes ruber*
	Haemulidae	1	†	*Pomadasys argenteus*
	Leiognathidae	1	†	*Leiognathus bindus*
	Sparidae	1	†	*Acanthopagrus arabicus*
		1	†	*Sparadnetx hasta*
	Siganidae	1	†	*Siganus canaliculatus*
	Scatophagidae	1	†	*Scatophagus argus*
15	35	50	†51Sp. *8 Sp.	59

†Marine Water Fish, ***Fresh Water Fish, ‡Chondrichthyes Fish.

Species composition

During the study period, 59 species belonging to 50 genera and 35 families were recorded. The lowest catch was observed in January, with 13 species, while the highest was in September, with 35 species, resulting in a monthly average of 23 species. Native species accounted for 13.56% of the total, with 8 species recorded. The proportion of alien and native species was equal, each representing 50% of the community. Marine species represented the highest proportion, comprising 86.44% of the total, with 51 species.

Correlation coefficient analysis revealed a strong positive correlation between temperature and the number of fish species (r= .837, P< 0.01), as well as a significant positive correlation between salinity concentration and the number of species (r= 0.731, P< 0.01). Fig. (2) illustrates the monthly changes in species composition and the number of individual fish at this site.

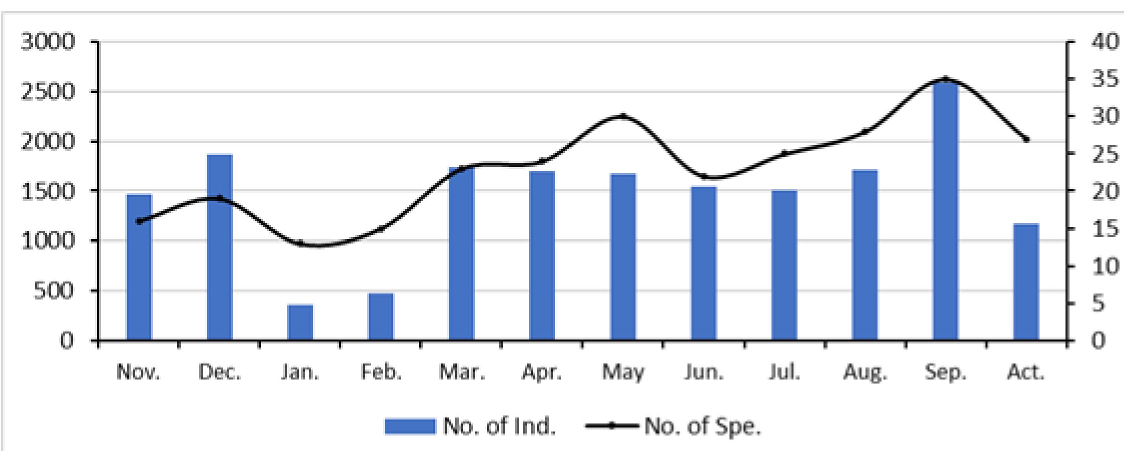

Fig. 2. monthly changes in the species composition and number of fish individuals

Species occurrence

The species were classified based on their monthly occurrence into three main groups. Table (2) and Fig. (3) illustrate the overlap of species (native, marine, and alien) according to Tyler's classification. The resident species group included 12 species, accounting for 20.34% of the total catch. The seasonal species group included 10 species (16.95%), ranking third after the resident group. The rare species group had the highest number of species, comprising 37 species (62.71%), based on the frequency of their monthly occurrence.

Table 2. Groups of fish species according to their frequency of occurrence in monthly fishing samples

Groups	Species				
	Occurrence Periods				
First group	**9 months**	**10 months**	**11 months**	**12 months**	**12 months**
Resident species	*O. aureus*	*J. belangerii*	*I. compierssa*	*J. sina*	*B. dussumieri*
20.34%		*B. orientalis*	*P. subviridis*	*T. whiteheadi*	*P. klunzingeri*
				T. ilisha	*A. arabicus*
					S. hasta
Second group	**6 months**	**6 months**	**7 months**	**7 months**	**8 months**
Seasonal species	*P. indicus*	*C. leucas*	*S. sihama*	*L. bindus*	*B. fuscus*
16.95%	*S. commersonnianus*	*A. thalassinus*	*N. nasus*	*S. argus*	
				C. gibelio	
Third group	**1 month**	**1 month**	**2 months**	**3 months**	**5 months**
Rare species	*L. vorax*	*P. argenteus*	*C. luteus*	*O. niloticus*	*P. abu*
62.71%	*S. triostegus*	*P. miles*	*P. melanostigma*	*T. lepturus*	*S. albella*
	P. niger	*C. multibarbus*	*E. glossodon*	*A. djedaba*	
	H. uarnak	*U. tragula*	*E. areolatus*	*S. longiceps*	
	S. commerson	*E. muticus*	*P. sephen*	*T. dussumieri*	**4 months**
	S. mokarran	*S. canaliculatus*	*T. crocodilus*	*E. tetradactylum*	*C. zillii*
	C. nudus	*C. chanos*	*C. dorab*	*T. mystax*	
	O. ruber		*P. microcephalu*		
	P. lineatus		*C. arel*		
	S. obtusata		*S. elongata*		

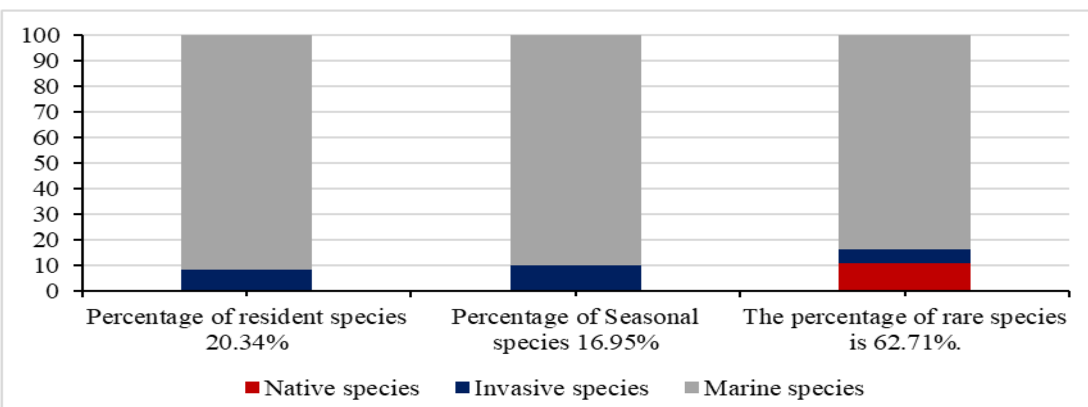

Fig. 3. Overlap of endemic, marine and invasive species within Tyler's division

Structure of families

Table (3) shows the monthly changes in the percentage composition of individual fish across 35 families. Six families were present in all sampling months: Engraulidae, Dorosomatidae, Mugilidae, Gobiidae, Sciaenidae, and Sparidae. The Pristigasteridae family appeared in 11 months. Mugilidae ranked first in abundance, with 4,934 individuals, accounting for 27.74% of the total catch. Within this family, *P. klunzingeri* contributed 76.57% of the total number of Mugilidae individuals.

The Engraulidae family ranked second, with 3,680 individuals (20.69%), with *T. whiteheadi* making up 87.30% of the family's total. Sciaenidae came third, comprising 2,264 individuals (12.73%), of which *J. sina* represented 76.5%. Fig. (4) illustrates these distributions.

Table 3. Monthly changes in the numerical values of the fish families of the study site

Fish Families	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Act.
Mugilidae	300	128	132	64	872	836	274	852	848	268	10	350
Engraulidae	244	656	20	104	106	232	541	188	28	820	613	128
Sciaenidae	488	440	18	27	270	20	135	108	40	132	250	336
Dorosomatidae	44	128	6	232	198	252	293	228	56	148	20	18
Sparidae	264	280	152	22	14	12	49	40	172	64	133	126
Pristigasteridae	40	80		2	8	90	54	60	4	172	146	68
Ariidae							9	16	16	4	584	2
Cichlidae	16	24	2		154	170	114	4	10	2	13	
Gobiidae	32	8	16	3	68	36	121	24	124	11	23	14
Sillaginidae	10	40			2				28	6	106	26
Leiognathidae	10				4	6	5		4	3	133	
Platycephalidae			2				3		24	6	77	46
Soleidae		16	8	3	6	4	9		64	15	261	18
Carangidae					2	4	8	12		5	70	22
Cyprinidae	16	32	8	12	26	20	2					
Polynemidae									72	16	20	
Haemulidae											89	
Scatophagidae		32				4	24	5		3	13	2
Trichiuridae					4	10	25	8		4		
Chirocentridae										30	3	6
Cynoglossidae											10	2
Carcharhinidae						2	1	1	3		1	1
Scombridae									8			
Belonidae									4		3	
Dasyatidae									4		1	
Synanceiidae					2		1				1	
Sphyraenidae											3	
Serranidae								2	1			
Plotosidae											3	
Mullidae												2
Siluridae				2								
Scorpaenidae											1	
Sphyrnidae										1		
Chanidae												1
Siganidae												1

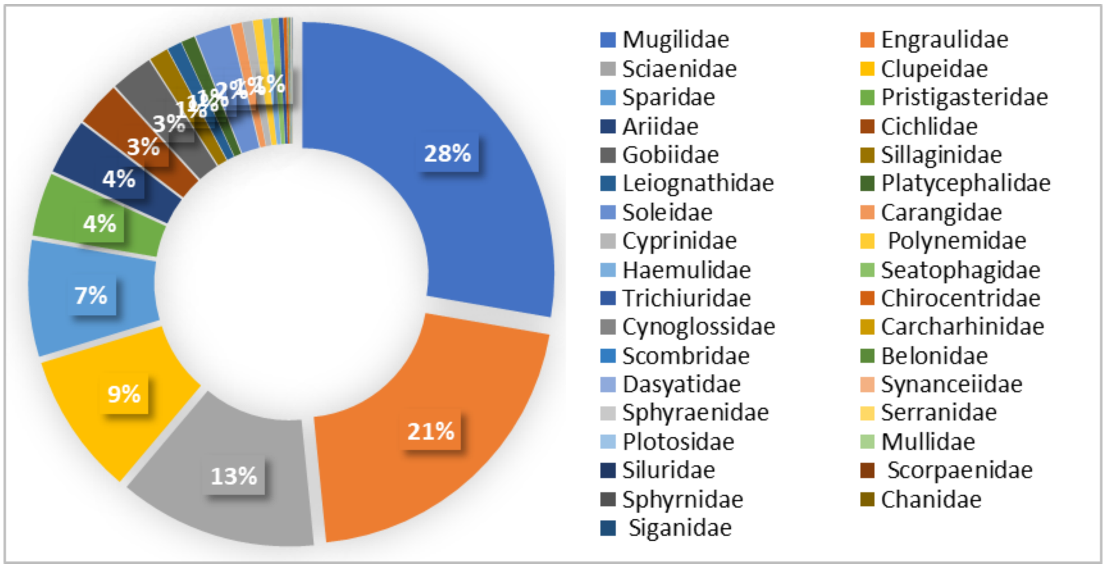

Fig. 4. The percentages of fish families at the Daura site

Relative abundance species

Table (4) shows the monthly changes in the numerical percentages of individual fish species. *P. klunzingeri* ranked first with a numerical percentage of 21.24% and a total of 3,778 individuals. *T. whiteheadi* came in second, representing 18.05% of the total catch with 3,213 individuals. *J. sina* ranked third, with a relative abundance of 9.74% and a total of 1,732 individuals. The numbers and percentages of the remaining species decreased gradually, with monthly and total abundances varying and reaching their lowest levels, as shown in Table (4).

Fig. (2) illustrates the monthly variation in the numerical abundance of individual species. The lowest abundances were recorded in January (364 individuals) and February (471 individuals), while the highest were observed in December (1,864 individuals) and September (2,587 individuals). In September, *A. thalassinus* and *T. whiteheadi* contributed the most to the total number of individuals, with 584 and 307 individuals, respectively—together accounting for 34.44% of the total for that month.

Correlation coefficient analysis showed a positive correlation between temperature and the number of fish individuals ($r = .589$, $P < 0.05$)

Table 4. Monthly changes in the numerical percentages of individuals of fish species in the study area

Fish Species	Nov.	Dec.	Jan.	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug.	Sep.	Act.
P. klunzingeri	15.0	0.9	1.1	6.8	46.0	44.3	7.9	39.5	44.0	11.9	0.4	28.6
T. whiteheadi	16.7	35.2	5.5	22.1	6.1	13.7	31.5	12.1	1.9	42.3	11.9	6.7
J. sina	21.9	17.2	5.0	4.7	15.4	1.2	6.0	5.9	2.4	6.3	7.3	20.5
T. ilisha	3.0	6.4	1.7	48.0	11.3	11.3	13.1	5.4	0.3	6.4	0.7	1.5
P. subviridis	4.9	5.6	32.4	6.4	3.5	5.0	8.5	15.5	12.2	3.7		1.4

A. arabicus	16.1	11.6	39.6	3.0	0.6	0.4	2.5	1.6	7.7	2.5	4.3	10.1
I. compierssa	2.7	4.3		0.4	0.5	5.3	3.2	3.9	0.3	10.1	5.6	5.8
A. thalassinus							0.5	1.0	1.1	0.2	22.6	0.2
J. belangerii	11.5	6.4		1.1	0.1		2.1	1.0	0.3	1.1	2.4	8.2
B. dussumieri	1.6	0.4	4.4	0.6	0.9	0.9	5.8	1.3	8.2	0.4	0.5	0.7
O. aureus	1.1	0.9	0.6		6.3	5.5	4.4		0.4	0.1	0.5	
T. dussumieri							0.9				9.5	2.9
B. orientalis		0.9	2.2	0.6	0.4	0.2	0.5		4.2	0.9	5.1	1.0
S. hasta	1.9	3.4	2.2	1.7	0.2	0.4	0.4	1.0	3.7	1.3	0.9	0.7
S. sihama	0.7	2.2			0.1				1.9	0.4	4.1	2.2
N. nasus		0.4		1.3	0.1	0.4	0.4	4.9	3.4	1.5		
T. mystax										5.6	2.3	1.4
S. albella						3.2	3.1	3.1		0.5	0.1	
L. bindus	0.7				0.2	0.4	0.3		0.3	0.2	5.1	
C. zillii					2.5	4.2	2.4	0.3	0.3			
P. indicus			0.6				0.2		1.6	0.4	3.0	3.9
S. elongata											5.0	0.5
B. fuscus	0.6				3.0	1.2	1.4	0.3		0.2	0.1	0.3
E. tetradactylum									4.8	0.9	0.8	
S. commersonnianus					0.1	0.2	0.2	0.3			2.6	1.9
C. gibelio	1.1	1.3	2.2	2.6	1.2	0.9	0.1					
P. argenteus											3.4	
S. argus		1.7				0.2	1.4	0.3		0.2	0.5	0.2
P. abu	0.6	0.4	2.8	0.4	0.8							
S. longiceps							1.0	1.3		0.2		
T. lepturus					0.2	0.5	1.1	0.5				
C. nudus										1.8		
A. djedaba							0.2	0.5		0.3	0.1	
O. niloticus		0.4				0.2						
C. arel											0.4	0.2
C. luteus					0.4	0.2						
E. muticus							0.4			0.2		
C. dorab											0.1	0.5
P. microcephalus											0.3	0.2
C. leucas						0.1	0.1	0.1	0.2		0.0	0.1
L. vorax		0.4										
S. commerson									0.5			
T. crocodilus									0.3		0.1	
O. ruber										0.4		
S. obtusata											0.1	
E. areolatus								0.1	0.1			
P. sephen									0.1		0.0	
P. melanostigma					0.1		0.1					
P. lineatus											0.1	
E. glossodon						0.1						
U. tragula												0.2
H. uarnak									0.1			
S. triostegus				0.4								
P. niger							0.1					
P. miles											0.0	

C. multibarbus											0.0	
S. mokarran										0.1		
C. chanos												0.1
S. canaliculatus												0.1

Environmental evidence

The overall diversity value was recorded at 2.74, as shown in Fig. (5). Monthly results indicated the lowest diversity in February (1.69) and the highest in September (2.69). The overall evenness value was 0.67, with the lowest monthly value observed in March (0.59) and the highest in November (0.79). The richness index for the region was 2.06, which closely matches the lowest monthly value recorded in January (2.03), compared to the highest value in September (4.33). The dominance index averaged 49%, with the lowest value in September (44%) and the highest in January (77%).

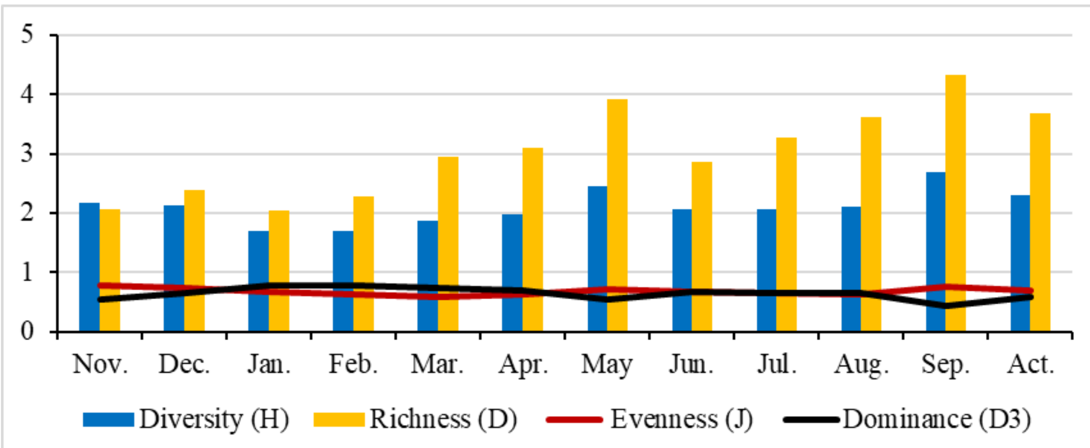

Fig. 5. Environmental indicators values for the study area

Relative importance index: (IRI%)

Fig. (6) shows the relative importance index (RII) values. The results indicated that *T. ilisha* ranked first, with an RII of 21.46% and a presence rate of 100%. *P. klunzingeri* ranked second with 18.31% and the same presence rate. *T. whiteheadi* held third place with 13.38%, followed by *J. sina* in fourth place (9.73%), *P. subviridis* in fifth (6.73%), and *A. latus* in sixth (6.08%).

These were followed by *I. compierssa* (3.86%), the bull shark *C. leucas* (3.11%), *S. hasta* (2.31%), and *J. belangerii* (2.23%).

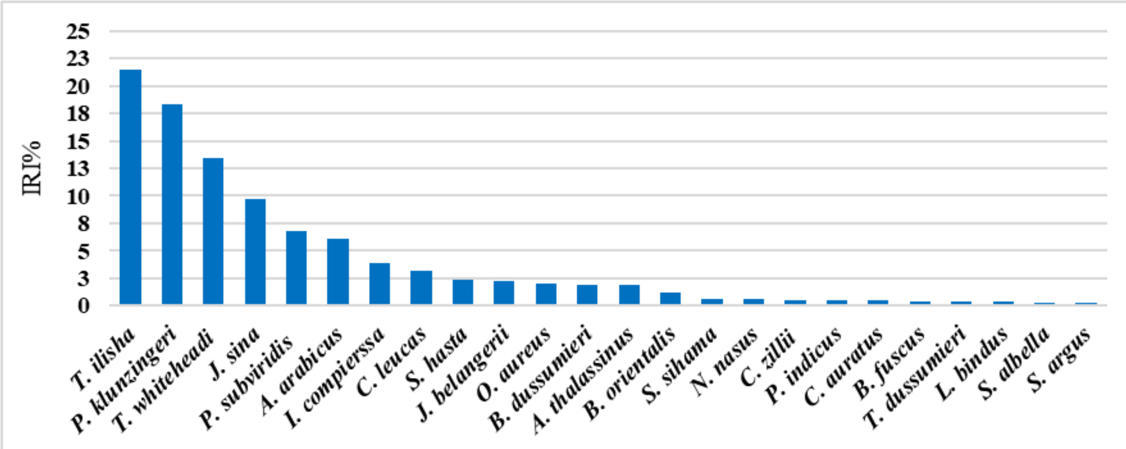

Fig. 6. Relative importance index of some fish species caught at station

Jaccard similarity index

Similarity in species composition was assessed between the baseline sample (November) and the subsequent study months to identify patterns of change over time. Fig. (7) shows that the trend line of predicted similarity ratios gradually declined throughout the study period, with the highest similarity recorded in March (69.57%) and the lowest in September (34.21%).

According to Table (5), which presents Jaccard index similarity ratios between different study months, the lowest similarity was observed between January and both March and April, with values of 0.8 and 1.3%, respectively. The highest similarity was recorded between March and April (97.8%) and between April and June (97.5%).

Pearson correlation analysis revealed that diversity and richness indices were positively correlated with salinity concentrations and water temperature, whereas the Jaccard similarity index, dominance index, and evenness index were negatively correlated with these factors.

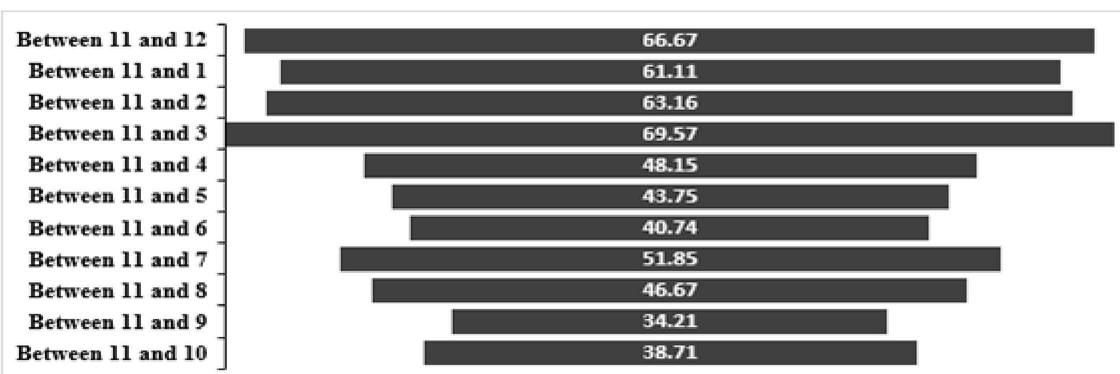

Fig. 7. Similarity ratios between the basic sample and the study months for the study area

Table 5. Percentages of Jaccard similarity index between study months

Month	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Nov.	100 %											
Dec.	73.8%	100 %										
Jan.	59.5%	38.9%	100%									
Feb.	35.8%	51.4%	10%	100%								
Mar.	53.6%	10.9%	0.8%	33.9%	100%							
Apr.	60.3%	26.1%	1.3%	39.5%	97.8%	100%						
May	65.0%	88.9%	15.5%	69.3%	36.7%	51.0%	100%					
Jun.	63.4%	26.4%	4.5%	30.7%	95.3%	97.5%	46.7%	100%				
Jul.	56.1%	3.9%	16.6%	9.4%	91.7%	88.1%	20.9%	92.1%	100%			
Aug.	66.9%	90.3%	13.1%	50.6%	34.5%	50.5%	92.3%	50.6%	24.0%	100%		
Sep.	23.9%	37.9%	11.6%	10.1%	4.5%	2.7%	30.9%	5.7%	3.7%	36.3%	100%	
Oct.	79.4%	29.1%	30.1%	18.6%	85.9%	86.6%	35.3%	89.9%	89.1%	42.1%	10.7%	100%

Environmental factors and multivariate analysis

The results shown in Fig. (8) indicate that the lowest water temperature was recorded in January at 13.8°C, gradually increasing to a peak of 34°C in July. The average temperature over the study period was 24.39°C.

pH values remained near neutral throughout the study. The lowest pH was recorded in March (7.32), and the highest in December (8.27), with an overall average of 7.72.

Salinity concentrations ranged from brackish levels during the first five months of the study to saline levels in the remaining months. The lowest salinity (1.5‰) was recorded in both November and March, while the highest (35.5‰) occurred in August. The overall average salinity was 17.14‰.

Dissolved oxygen levels averaged 8.22 mg/L. The lowest concentration was observed in July (5.7 mg/L), and the highest in January (11.1 mg/L).

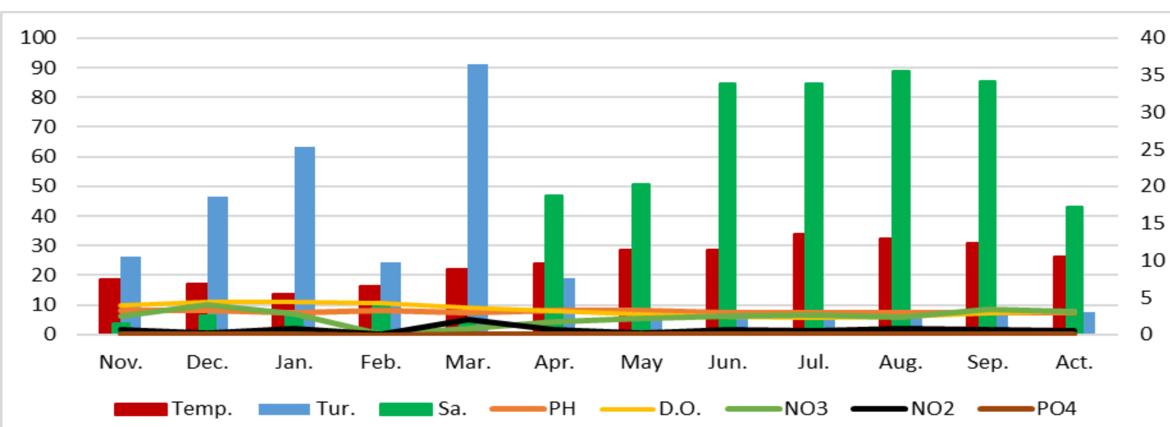

Fig.7. Values of environmental factors for the study area

Water turbidity peaked in March at 91.3 NTU, then decreased to 5.61 NTU in June, with an overall average of 26.01 NTU. Nitrate concentrations reached their highest value in December (10.1µg/ L) and their lowest in February (0.15µg/ L), with an average of 5.87µg/ L. Nitrite was undetectable in February (0.0µg/ L) and peaked in March at 5.0µg/ L, averaging 1.54µg/ L over the study period. Phosphate levels averaged 0.029mg/ L, with the lowest values recorded in February (0.001mg/ L) and January (0.009mg/ L), and the highest in August (0.096mg/ L).

Water temperature was positively correlated with salinity (r= 0.928, P< 0.01), and negatively correlated with dissolved oxygen (r= –0.972, P< 0.01) and turbidity (r= –0.654, P< 0.05). Salinity was negatively correlated with dissolved oxygen (r= –0.932, P< 0.01) and turbidity (r= –0.747, P< 0.01). pH showed a negative correlation with nitrite (r= –0.594, P< 0.05), while nitrite was positively correlated with turbidity (r= 0.643, P< 0.05).

Table (6) presents the loadings, correlations, and distribution ratios of environmental factors from the supplementary variables analysis, which complements the principal components analysis. Fig. (8) shows the results of this analysis, highlighting the effect of measured environmental factors on the number of species and individuals, along with the stability of factor loadings and vector directions throughout the study period. The figure illustrates a positive correlation between species/individual counts and water temperature, salinity, phosphate, and nitrate concentrations. In contrast, negative correlations were observed with pH, dissolved oxygen, water turbidity, and nitrite.

Table 6. Loadings, correlations and distribution ratios of factors in the supplementary variables

Environmental factors	**F1**		**F2**		**F3**	
	a	***b***	***a***	***b***	***a***	***b***
Temp.	0.95	23.38	0.14	1.09	-0.14	1.74
pH	-0.47	5.64	-0.76	30.60	-0.06	0.32
Sal.	0.97	24.31	0.01	0.004	-0.1	0.84
D.O.	-0.94	22.89	-0.11	0.61	0.23	4.43
Tur.	-0.76	15.13	0.56	16.55	0.18	2.97
NO_3	0.34	2.98	-0.22	2.57	0.77	50.41
NO_2	-0.13	0.48	0.96	48.29	0.01	0.02
PO_4	0.44	5.15	0.07	0.26	0.68	39.24
No. Sp.	0.77		0.12		-0.01	
No. Ind.	0.53		0.12		0.31	
Eigenvalue	3.905		1.91		1.192	
Variability (%)	48.808		23.873		14.895	
Cumulative %	48.808		72.682		87.577	

a**:** Correlations between variables and factors**;** ***b*****:** Contribution of the variables **(%)**

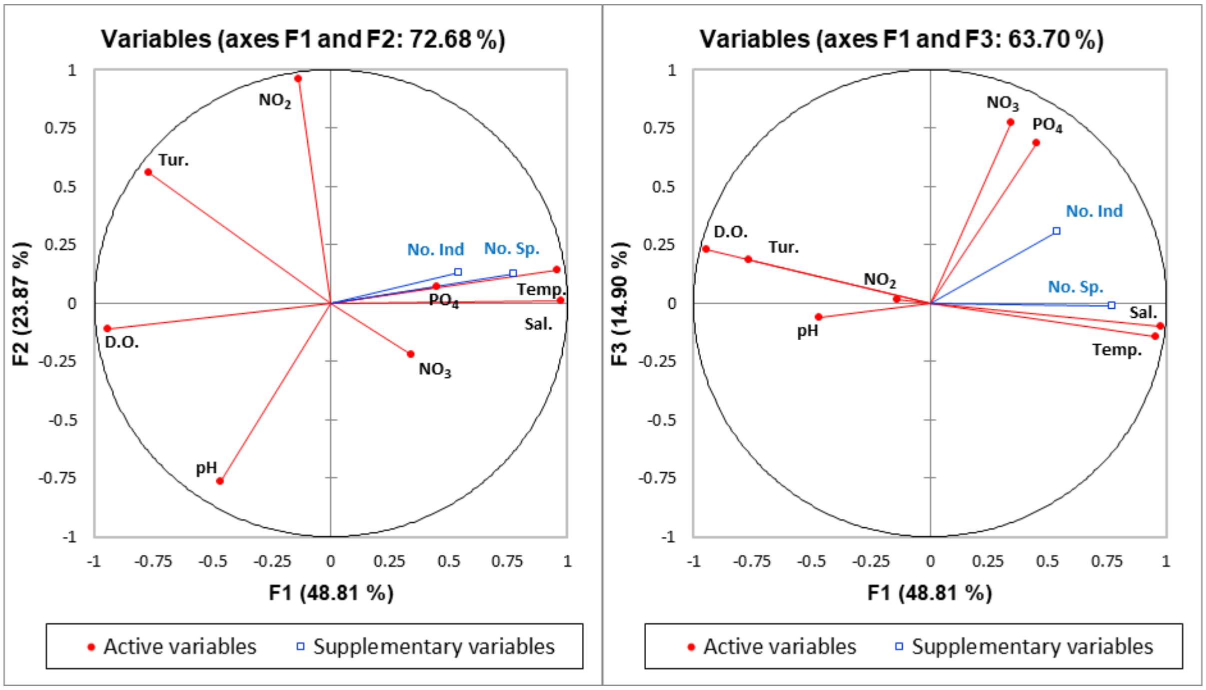

Fig. 7. Analysis of supplementary variables for the effect of factors on fish species and individuals in the fishing area

DISCUSSION

Freshwater ecology is a specialized subfield of ecological science that focuses on the interaction between aquatic organisms and their surrounding water-based environments. It involves studying both the living organisms and the physical and chemical characteristics of freshwater systems, providing vital insights into the health, stability, and needs of these ecosystems **(Bănăduc *et al*., 2022)**.

The results of the current study revealed notable variation in the number of fish species in the study area. Seasonal patterns showed an increase in species richness during the summer months. The number of species was positively correlated with salinity concentrations and water temperatures (Fig. 2).

Previous studies have highlighted the ecological importance of the Shatt al-Arab as a reproductive, nursery, and feeding ground for many marine fish species in the Iraqi marshes, particularly the East Hammar Marsh **(Mutlak *et al*., 2008)**. It also serves as a spawning ground for native marine species, such as *A. arabicus* and *A. thalassinus*, which were found in juvenile stages. The high proportion of marine fish in this study aligns with the observed positive correlation between salinity levels and species abundance. This shift coincides with declining water levels in the Shatt al-Arab, allowing saltwater from the Arabian Gulf to intrude further upstream. This salinity intrusion facilitates the entry of more marine species into the region.

Climate change plays a significant role in this process. As sea levels rise and saltwater intrudes into freshwater systems, key freshwater species may be forced to migrate or perish, disrupting food webs **(EPA, 2015)**. Field observations during the study confirmed that increased salinity prompted the northward migration of salt-intolerant species. This phenomenon was reflected in the concentration of fishing activity north of Basrah at that time, and similarly reported in the Hammar Marsh by **Mutlak (2012)**.

The increase in salinity led to the appearance of marine species previously unrecorded in the area, including *O. ruber*, *S. mokarran*, *C. chanos*, *P. lineatus*, and others—despite the site being tens of kilometers inland from the estuary. Simultaneously, the numerical and qualitative abundance of freshwater resident fish declined, with only one salt-tolerant tilapia species persisting (Table 5). Mortality was observed in *C. gibelio* individuals, while marine species reached their peak abundance in September (Fig. 2).

Historical data from **Hussain *et al*. (1999)** recorded eight freshwater fish species in the Shatt al-Arab estuary in 1994. In contrast, this study found a decline in freshwater and endemic species, alongside a rise in marine and invasive species. Sensitive native species—such as *Mesopotamichthys sharpeyi*, *Luciobarbus xanthopterus*, *Arabibarbus grypus*, *Cyprinus carpio*, *Cyprinion macrostomum*, *Cyprinion kais*, and *Luciobarbus kersin*—were completely absent from the catch. The *Cyprinidae* family, typically dominant in freshwater environments, ranked low due to the influx of marine species driven by salinity intrusion.

The consistent occurrence of resident species suggests year-round availability. According to **Tyler (1971)**, resident species form the core of a stable fish community. **Ali (1985)** added that seasonal species migrate for feeding or reproduction during specific times of the year.

This study also contrasts with previous research in terms of species residency. **Hussain *et al*. (1997)** reported 7 resident, 8 seasonal, and 10 rare species. **Resen *et al*. (2014)** found only 5 resident, 2 seasonal, and 2 rare species, while **Lazim (2014)** identified 19 resident, 8 seasonal, and 31 rare species. In the present study, resident species ranked second after seasonal species, and their proportion nearly equaled that of rare species—indicating a clear ecological imbalance. Ideally, the community should be dominated by resident species, followed by seasonal and rare types, as described by Tyler. Fig. (3) further shows a persistent dominance of marine and invasive species, while local species were found only among the rare group.

This imbalance is largely attributed to seasonal salinity fluctuations caused by reduced water inflows from the Tigris and Euphrates rivers originating outside Iraq **(Bakhit,**

2008; Al-Hussaini & Al-Sandouk, 2009). The diversion of the Karun River, which once contributed 33% of the region's water supply, further exacerbated the issue **(ESCWA, 2013)**.

The study concludes that even short-term changes in environmental parameters can cause rapid shifts in species composition. Restoring ecological balance, even with intervention, would require a prolonged period. While exotic species persisted to a limited extent, they demonstrated greater resilience than native species. Only 7 of the 59 fish species appeared in all monthly samples; others were absent for one or more months. *P. klunzingeri* ranked first in abundance, followed by *T. whiteheadi* and *J. sina*. By contrast, in earlier studies such as **Lazim (2009)**, *P. abu* ranked first and *C. gibelio* second. *C. gibelio* also dominated in the findings of **Mohamed *et al*. (2012)** and **Lazim (2014)**. The trend was consistent in **Mohamed *et al*. (2015)**.

The dominance of *C. gibelio* in past studies reflected its numerical advantage over other local species, both tolerant and sensitive. **Hussein *et al*. (2000)** emphasized that invasive species, like *C. gibelio*, can disrupt native populations by interfering with food chains. This explains the reduced abundance of native, salt-intolerant species. **Karr and Chu (1997)** noted that a decline in such species is a strong indicator of ecological degradation, while their abundance is a sign of ecosystem health. In this study, both native and invasive species were impacted by rising salinity, prompting northward migration. Environmental indicators are essential for evaluating the health and structure of ecological communities **(Štreimikienė, 2015)**.

The environmental indicators in this study peaked in September due to elevated temperatures and salinity, which facilitated the influx of marine species and increased biodiversity, evenness, and species richness, while lowering the dominance index—a positive ecological sign. The relative importance index, combining abundance and biomass, identified *T. ilisha*, *P. klunzingeri*, and *T. whiteheadi* as the most dominant species. The linear prediction trend in Fig. (5) shows a continuous decline in similarity with the baseline sample, indicating increasing ecological change and marine intrusion.

Compared to past research **(Hussain *et al*., 1995; 1997; Jassim, 2003; Younis, 2005; Lazim, 2009; Mohamed *et al*., 2010; 2012; 2013; Lazim, 2014; Resen *et al*., 2014)**, this study reports higher environmental indicator values. These values reflect a profound shift in ecosystem structure due to environmental changes.

From Table (6), it is evident that salinity and water temperature play a primary role in determining species richness and abundance. Principal components analysis showed that these factors account for 47.69% of the total influence on fish diversity and abundance, indicating a strong positive effect. This suggests that the fish populations in the area are predominantly thermophilic and euryhaline. Meanwhile, dissolved oxygen and water turbidity had a negative influence, contributing 38.02% of the overall impact, indicating their role in reducing ecological diversity in the region.

CONCLUSION

Salinity concentrations and prevailing water temperatures significantly influenced the presence, distribution, and abundance of the fish community in the study area. The presence and abundance of freshwater fish were negatively affected, while the qualitative increase in marine fish was closely associated with rising salinity levels. Other environmental indicators also pointed to a fundamental shift in fish community composition, providing clear evidence of ecological imbalance in the region.

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