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Assessing Integrity of Aquatic Ecosystem in the Southern Part of the Euphrates River Using Fish as Bio-Indicators

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ABSTRACT

The state of the world's rivers is increasingly disturbed and requires a comprehensive understanding and appropriate conservation measures, and hence assessing the river health provides essential information for conservation. A set of metrics based on biomes was designed to evaluate the southern part of the Euphrates River; the fish community consisted of twenty-three species, with the highest abundance recorded for the endemic, invasive, and migratory species, respectively. The fish composition was divided into three groups; the species richness group was distinguished by the correlation of the region's richness index with the number of endemic fish species and marine migratory species. Fish community composition showed a close relationship with the final index value through its positive correlation with the percentage of the sensitive species ($r=0.683$, $P=0.01$) and the inverse correlation with *Planiliza abu* ($r= -0.629$, $P=0.02$). The nutritional composition group was characterized by the dominance of the herbivores species, and the final index value was correlated to the proportion of the carnivorous species ($r=0.803$, $P=0.002$). The value of the evidence was 56.53%, which is within the classification of moderate environments. The study in this paper demonstrated that the selected measures were strongly associated with the direction of each measure's effect and the flexibility of the response of the final value of the evidence to it. The multivariate statistical techniques approach was also used to evaluate the effectiveness of these measures. The technique showed that out of twelve units in the index, nine were efficient, and three were less efficient in sensitivity to the surrounding environmental changes. Biomonitoring is essential to determining organisms' responses to the environmental degradation factors. It provides results and descriptions of the river health that affect water quality, enabling reliable management of water resources and the development of plans to measure environmental risks.

INTRODUCTION

Biomonitoring is generally defined as the systematic use of living organisms or their responses to determine the state or changes of the environment. It is also known as a method of monitoring the impact of external factors on ecosystems and their development over time or verifying the difference between different sites **(Rosenberg, 1998; Markert *et al*., 1999)**. Bodies of water are subject to environmental pressures that act on different scales and affect the ecosystems and habitats of their fish populations. However, the relative influence of different scale-related variables on the composition and function of these assemblies is not well understood; therefore, many studies that address the relationship of communities to levels of environmental variables use bio-integrity indicators **(Machado *et al*., 2011)**. Local variables, such as water quality, energy sources, interactions, and the shape of the water body, help determine the composition of fish populations. Watersheds are affected by many factors, such as surface geology, soil type, bottom topography, and climate **(Wang *et al*., 2003;Terra *et al*., 2016)**.The shortage of biological monitoring programs affects the lack of an integrated view of the environmental status of water bodies, which hinders the establishment of rational ecological restoration and protection plans **(Hughes *et al*., 2000; Hughes *et al*., 2004)**. Since streams and rivers are among the most vulnerable ecosystems, there are pressing demands for comprehensive, systematic approaches to assess these systems' actual state and monitor their rate of change.Physical, chemical, and bacterial measurements usually form the basis of environmental monitoring since they provide a complete set of information for sound water management **(Malmqvist &Rundle, 2002)**. Rapid changes in runoff hydrology are difficult to estimate and cannot reflect the integration of many environmental factors and the long-term sustainability of the riverine ecosystems **(Saunders *et al*., 2002)**. Moreover, complementary biomonitoring has proven to be essential to traditional monitoring techniques, since it provides the possibility of obtaining an ecological overview of the status of streams or rivers **(Li *et al*., 2010)**.The Euphrates River suffers from many environmental pressures, represented by the lack of water flows from the source due to the Upper Basin projects, which have changed its physical, chemical, and biological characteristics, especially in the southern part, whose water revenues are almost declining. Owing to the lack of rain ascribed to climate change, feedback occurs in water revenues from the Tigris to the Euphrates, which contributes to changing the biodiversity of the river.The current study aimed to evaluate the water quality of the southern part of the Euphrates River using the integrated biological index (IBI) and to verify the quality of the standards used for that guide, the statistical technique of principal components analysis was applied.

MATERIALS AND METHODS

Fish were collected monthly from the Euphrates in the area near its connection with the Tigris, where the Shatt al-Arab is formed,from January to December, with one fishing day in the middle of each month, according to the coordinate 30°58'30.17"N 47°21'52.00"E (Fig.1). Four fishing methods were used: floating and fixed trap nets, bottom trawl nets, and enclosure nets.The fish caught were classified according to **Carpenter *et al*. (1997)** and **Coad (2010)**. Fish species were divided according to their geographical origins (endemic or exotic), and the diet of the caught species was examined. The IBI was calculated based on the method outlined by **Minns *et al*. (1994)**.

Its unit scores were determined from zero to 10, and the units were classified into a group that increased the index value and another group that lowered it. 10 points were assigned for the values of the highest units that improve the environmental quality. The remaining results were calculated by the equation: unit value = (A/B)*10,where A = the obtained value, and B= the upper value. This equation applies to metrics that increase with an improvement in the environmental quality. 0 was given to the values of their upper units, and the rest of the results were calculated by the equation: unit value = (1-A/B)*10.The index value was between 0- 100. These values were classified as very poor (0-20), poor (21-40), moderate (41-60), good (61-80), and excellent (>80).Twelve units were selected to measure the life integration index out of three main groups (Table1). The richness index was calculated from the equation of **Margalefe (1968)**: D = S-1/ln N; S = number of species, and N = the total number of individuals in the sample. The program XLSTAT: version 2016.02.28451was used to perform the statistical analysis.

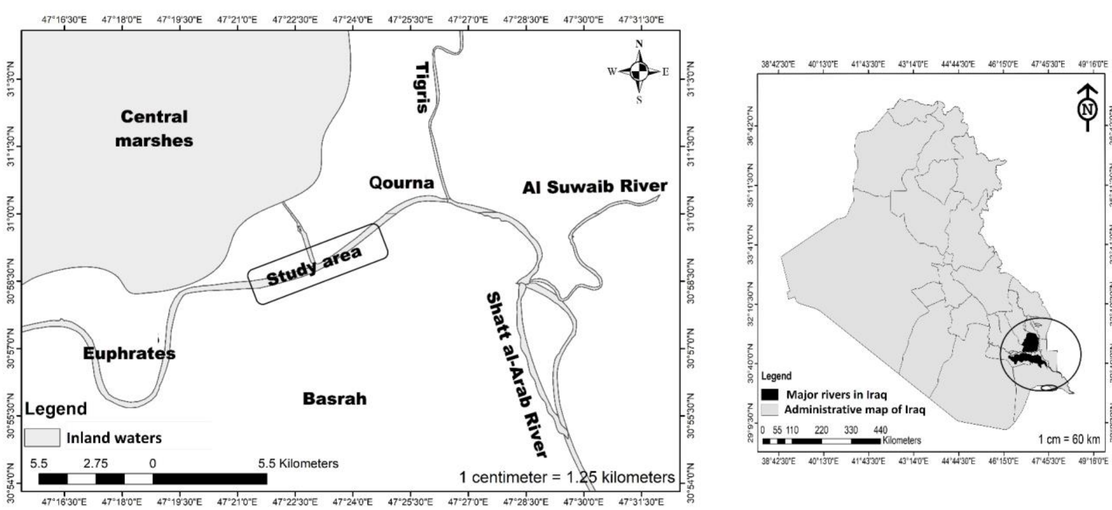

Fig. 1.A map showing the location of monthly sample collection

Table 1. Totals and units used to measure the integrated biologigal index

A-Species richness group	**B- Fish community composition group**	**C - Nutrition composition group**
1-The number of endemic species	5-% for individuals of tolerant species	9-% for herbivores species
2-The number of introduced species	6-% for individuals of sensitive species	10-% for carnivorous species
3- Number of migratory species	7-% for the species *Planiliza abu*	11-% for omnivorous species
4- Richness of species	8-% for the species *Oreochromis aureus*	12-% for detritivorous species

RESULTS

1.Biodiversity and fish composition of the study area

The fish composition of the study area consisted of twenty-three species belonging to eleven families; it included ten endemic species, eight introduced species, and five marine migratory species, as shown in Table (2). The diversity percentage reached 43.48, 34.78, and 21.74%, respectively. The highest specific abundance, of the sixteen species, was recorded during July and November, while the lowest was in February, with ten species. The relative numerical abundance of the endemic species was 39.35%, while the relative abundance of the introduced species was 60.14%, and the lowest numerical percentage of 5.29% was recorded for the marine species.

Table 2. Composition of fish families and species in the study area, with a description of some evidence units.

Family name	Scientific name of the species	Origin, sensitivity, and nutrition of the species
Cyprinidae	*Carassius gibelio* (Linnaeus, 1758)	E T O
Cyprinidae	*Alburnus mossulensis* (Heckel, 1843)	F O
Cyprinidae	*Carasobarbus luteus* (Heckel, 1843)	F S O
Cyprinidae	*Leuciscus vorax* (Heckel, 1843)	F S C
Cyprinidae	*Cyprinus carpio* (Linnaeus, 1758)	E O
Cyprinidae	*Acanthobrama marmid* (Heckel, 1843)	F O
Cyprinidae	*Hemiculter leucisculus* (Basilewsky, 1855)	E O
Cyprinidae	*Mesopotamichthys sharpeyi* (Günther, 1874)	F S H
Cyprinidae	*Hypophthalmichthys nobilis* (Richardson, 1845)	E D
Cyprinidae	*Garra rufa* (Heckel, 1843)	F S O
Cyprinidae	*Ctenopharyngodon idella* (Valenciennes, 1844)	E H
Engraulidae	*Thryssa whiteheadi* (Wongratana, 1983)	M C
Heteropneuetidae	*Heteropneustes fossilis* (Bloch, 1794)	E C
Mastacembelidae	*Mastacembelus mastacembelus* (Banks,1794)	F S C
Mugilidae	*Planiliza abu* (Heckel, 1843)	F T D
Mugilidae	*Planiliza subviridis* (Valenciennes, 1836)	M D
Sillaginidae	*Sillago sihama* (Forsskal, 1775)	M C
Siluridae	*Silurus triostegus* (Heckel, 1843)	F S C
Sparidae	*Acanthopagrus arabicus* (Iwatsuki, 2013)	M C
Bagridae	*Mystus pelusius* (Solander, 1794)	F S C
Cichlidae	*Oreochromis aureus* (Steindachner, 1864)	E T H
Cichlidae	*Coptodon zillii* (Gervais, 1848)	E H
Clupeidae	*Tenualosa ilisha* (Hamilton, 1822)	M D

F- Endemic species E- Introduced species M- Marine species S- Sensitive species T- Tolerant species O- Omnivorous species D- detritivorous species H- herbivores species C- Carnivorous species.

2.Environmental condition of the study area

2.1. Species richness group

The highest abundance of the endemic fish species, with seven species, was recorded in March, August, and October. The lowest abundance, with five species, was recorded in February, May, and June.The individuals of three species in this unit constituted 87.48% of its total individuals, including *Planiliza abu*, *Alburnus mossulensis* & *Carasobarbus luteus*. Fig. (2) describes the monthly changes in the values of the integrated biological index. The highest diversity of the exotic fish, with six species, was recorded in January and July. The lowest diversity, with three species, was recorded in April. Individuals from two species, *Oreochromis aureus* and *Carassius gibelio*, accounted for 85.16% of the total numerical composition of the introduced fish. It was noted that, November was the highest month for the catch of five species of migratory marine fish, while none of them was caught during January and February; two species represented the highest percentage of individuals caught during the study period, reaching 74.21%: *Tenualosa ilisha* & *Thryssa whiteheadi*. In July, the highest values of the richness index was 2.58, with a diversity and numerical abundance reaching 16 and 333, respectively; the lowest percentage recorded was 1.61 during February, with a diversity and numerical abundance of 10 and 261, respectively, and the total value of the richness index for the fishing area was 2.62, with a total diversity and numerical abundance of 23, 4380. Remarkably, the richness index values were affected by the number of the endemic and migratory species, as its values have a positive correlation with them ($r = 0.623$, P-values= 0.030, $R^2= 0.39$; $r = 0.616$, P-values= 0.033, $R^2= 0.38$).

2.2.Fish community composition group

The highest percentage reached 88.58% in September, and the lowest was 36.69% in March, with a total percentage amounting to 73.54% of the total fish population. Note that 66.45% of these species were exotic, especially *Oreochromis aureus*, which is believed to be the most tolerant to many pollutants due to its presence at a high rate of 34.52% of the total number caught; the highest percentage was recorded at 57.22% during November, while the lowest percentage was recorded at 7.66% during February.

The endemic *Planiliza abu* is also considered a highly tolerant species in the Iraqi aquatic environment. Its percentage, 24.66%, included approximately a quarter of the total catch. The highest value caught was during September, reaching 62.40%, and the lowest was 6.15% at the beginning of the study.

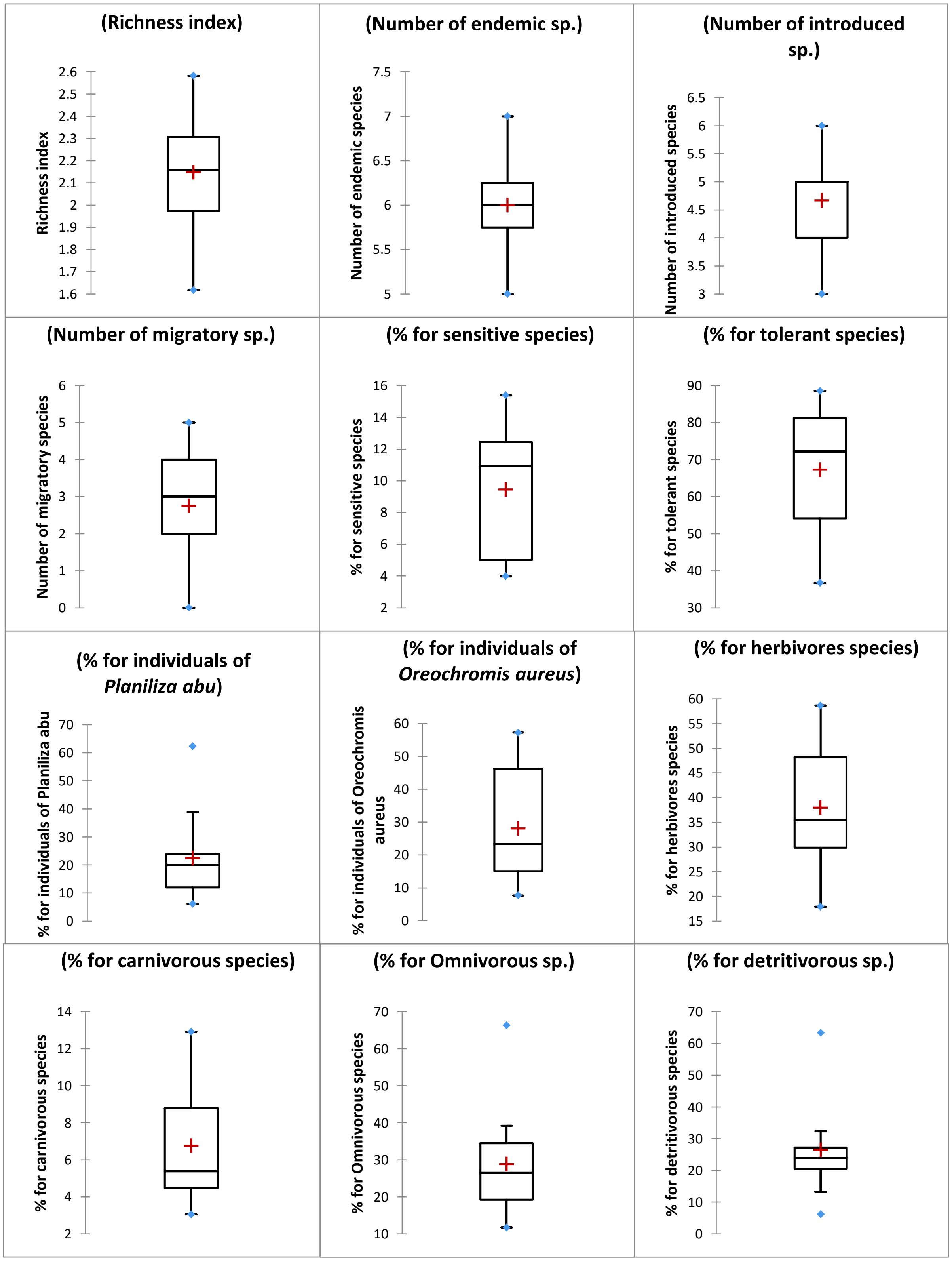

Fig. 2. Description of the values of the integrated biological index units during the study

This unit included seven species that were distinguished by variations in the rates of their monthly appearance, from twelve months, such as *Carasobarbus luteus* and *Leuciscus vorax*, to only one month, represented by the species *Mystus pelusius*. It is noted that the two species, *Mastacembelus mastacembelus* and *Garra rufa*, are highly sensitive to environmental conditions. They were once characterized by their abundance and spread throughout the southern flats. This unit is considered a qualitative indicator of water quality. The highest abundance of this unit was 15.38% during March, and the lowest was 3.98% in December, with a total catch rate of 8.29%. The majority of individuals in this unit were included in three species, with a rate of 96.51%. In terms ofnumerical abundance, the species are*Carasobarbus luteus*, *Leuciscus vorax*, and *Silurus triostegus*.

The values of the percentage of tolerant species were directly correlated with the percentage of individuals of the species *Planiliza abu*, as well as with the percentage of individuals of the species *Oreochromis aureus* (r = 0.586, *P*-values = 0.045, R^2 = 0.34), (r = 0.693, *P*-values = 0.013, R^2 = 0.48, respectively), while inversely correlated with the percentage of individuals of the sensitive species (r = -0.586, *P*-values = 0.045, R^2 = 0.34).

2.3. Nutrition structure group

The metrics of the herbivore fish species included four species, three of which were the introduced species, constituting 99.67% of the total abundance of this unit, and the rest of the percentage was attributed to the sensitive endemic species *Mesopotamichthys sharpeyi*, which has been present for four months, and the competition of the alien species appears clearly on these metrics, This unit represented 41.51% of the nutritional composition of the studied area, as shown in Fig. (3). The highest catch value was in November, reaching 58.67%, while the lowest was 17.91% in September. This unit was positively correlated with the percentage of individuals of the species *Oreochromis aureus*, with r= 0.830, *P*- values= 0.001, and R^2= 0.688. This species represented 83.17% of the total percentage of this unit. The detritivorous species ranked the second, with individuals accounting for 27.72% of the total abundance. The highest rate was caught in September (63.39%), and the lowest percentage was 6.15% at the beginning of the study. The *Planiliza abu* fish constituted 88.96% of the composition of this unit, as they were positively correlated to it (r= 0.962, *P*-values= < 0.0001, R^2= 0.925). The percentage of the omnivorous fish individuals came in third, reaching 24.57%. *Carassius gibelio* represented 58.46% of the individuals in this unit.The highest percentage caught was 66.39% recorded in January, and the lowest was 11.37% in November.

The relative abundance of the members of carnivorous species was the lowest in the trophic composition group, reaching 6.21%. The highest values were caught in July, with a value of 12.91%, and the lowest was in September with 3.04%. This unit included eight species, half of which were sensitive endemic species, three marine species, and one exotic species. Therefore, this unit was directly related to the sensitive species (r = 0.624, *P*-values= 0.030, R^2= 0.39).

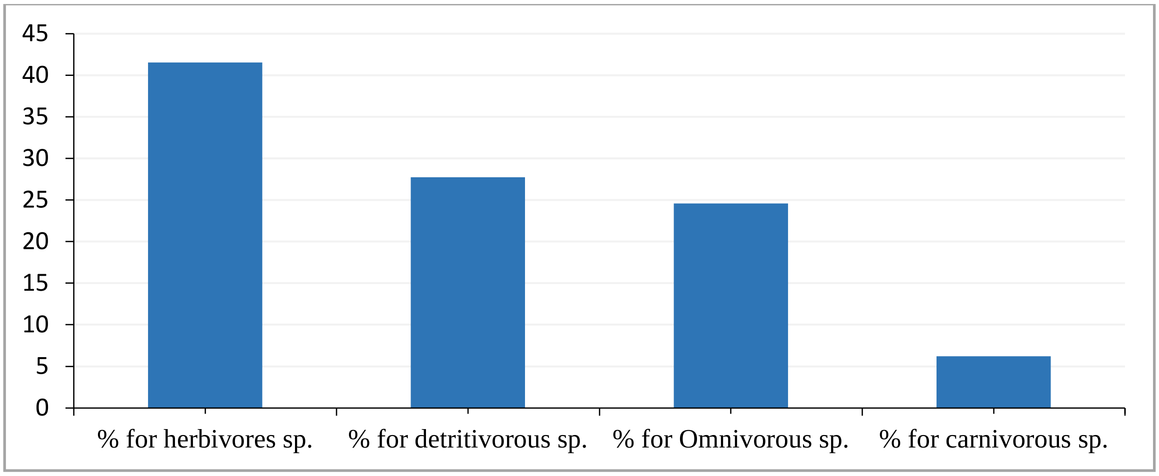

Fig. 3. Nutritional composition of the relative abundance of individual species

3.Verifying the efficiency of directory units

The efficiency and effectiveness of the units used in this index for this region were verified by using the statistical technique of the principal component analysis (PCA); its purpose is to know the proportions of influence, distribution, and contribution of the variables for each component, i.e., the units of evidence and the eigenvectors, and the proportions of the cumulative variance for them (Fig. 4). It shows the values of the eigenvectors and the percentages of cumulative variance for the units used in this index. The values of the three axes (F1, F2, and F3) explain the eigenvectors of the study data appropriately since their cumulative percentage of variance reached 74.31%, which is a percentage during which it is possible to interpret the eigenvectors statistically, especially the first vector because it gives an idea about the importance of the units under study; the contribution percentages of the rest of the units are shown in Table(3), where the best units used in the index were in the F1 vector, specifically 5.52b ≥, in the F2 vector b ≥ 6.41, and finally in the F3 vector b ≥ 6.32. Also, the correlation ranges of the units in the first vector (F1) were large, ranging from 0.916 to 0.826. This indicates that these units respond to and sense the environment to a wide and varying extent.

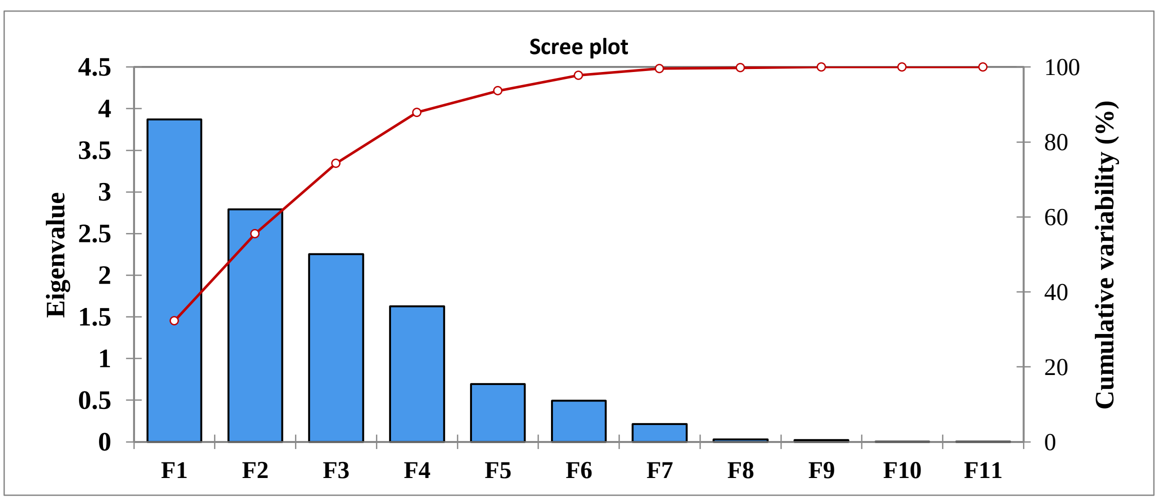

Fig. 4. Eigenvectors and cumulative variance of the units used in the IBI

Table 3. Correlated variables between index units, vectors (F), and eigenvalues for PCA analysis

Variable (Unit of index)	F1		F2		F3	
	a	b	A	B	a	b
Richness index	0.05	0.06	0.65	14.94	0.62	16.98
number of endemic sp.	-0.08	0.17	0.42	6.41	0.62	17.05
number of introduced sp.	-0.21	1.1	-0.15	0.8	0.07	0.25
Number of migratory sp.	0.71	12.94	0.57	11.48	0.21	1.91
% for the species *P. abu*	0.53	7.3	-0.64	14.61	0.53	12.4
% for the species *O. aureus*	0.77	15.29	0.46	7.54	-0.37	6.23
% for ind. of sensitive sp.	-0.48	6.04	0.28	2.91	0.2	1.85
% for ind. of tolerant sp.	0.92	21.66	-0.16	0.92	0.03	0.03
% for herbivores sp.	0.46	5.52	0.63	14.19	-0.54	13.08
% for carnivorous sp.	-0.46	5.57	0.62	13.66	0.54	12.85
% for Omnivorous sp.	-0.83	17.6	-0.16	0.9	-0.21	1.93
% for detritivorous sp.	0.51	6.75	-0.57	11.63	0.59	15.44
Eigenvalue	3.87		2.79		2.25	
Variability %	32.27		23.27		18.77	
Cumulative %	32.27		55.54		74.31	
(a) = Correlation between variables and factors						
(b) = Contribution of variables (%)						

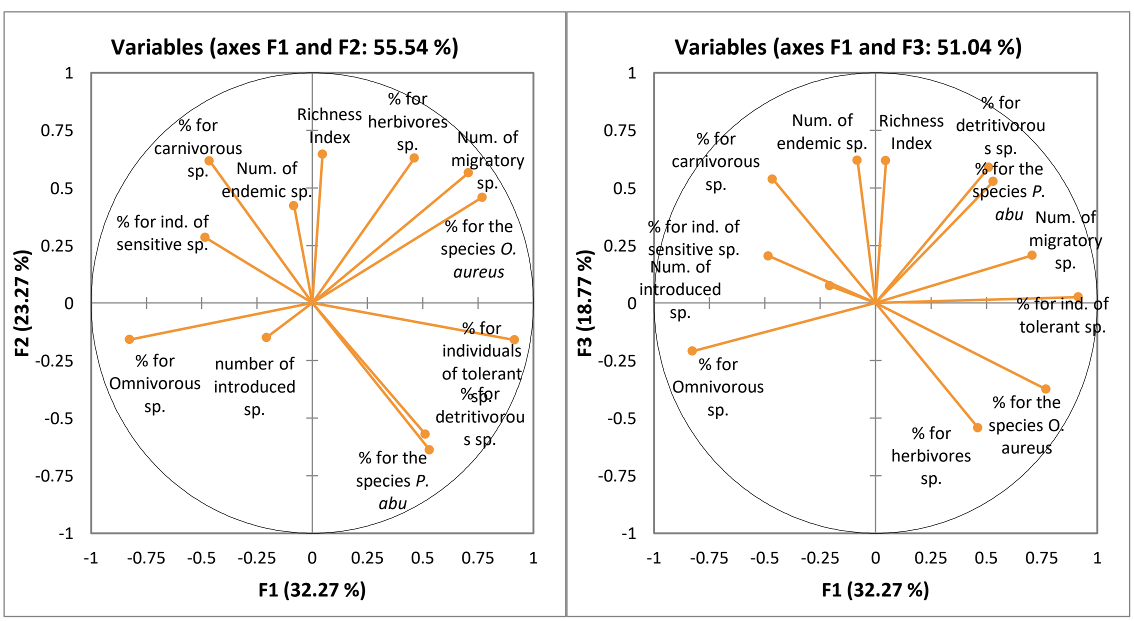

Fig. 5. Principal component analysis of the units used in the IBI for the study area

4- The value of the integrated biological index (IBI)

The monthly unit score values for the integrated biological index were measured. Fig. (6) shows the unit score values in the three selected groups during the study period; data in Fig. (6) record the difference in score values according to the scales that should increase or decrease with increasing or decreasing the environmental disturbance.

Fig. (7) represents the changes in the monthly integrated biological index values. The highest index values reached 75.66% in March, classifying the environment as good, while the lowest values in September reached 39.98%, classifying the environment as poor. There were no statistically significant quarterly differences between the monthly index values (P= 0.896, F= 0.195). Calculations showed that the Euphrates River ecosystem in the fish survey area was classified under the temperate environment assessment, with the final life integrity index values reaching 56.53%.

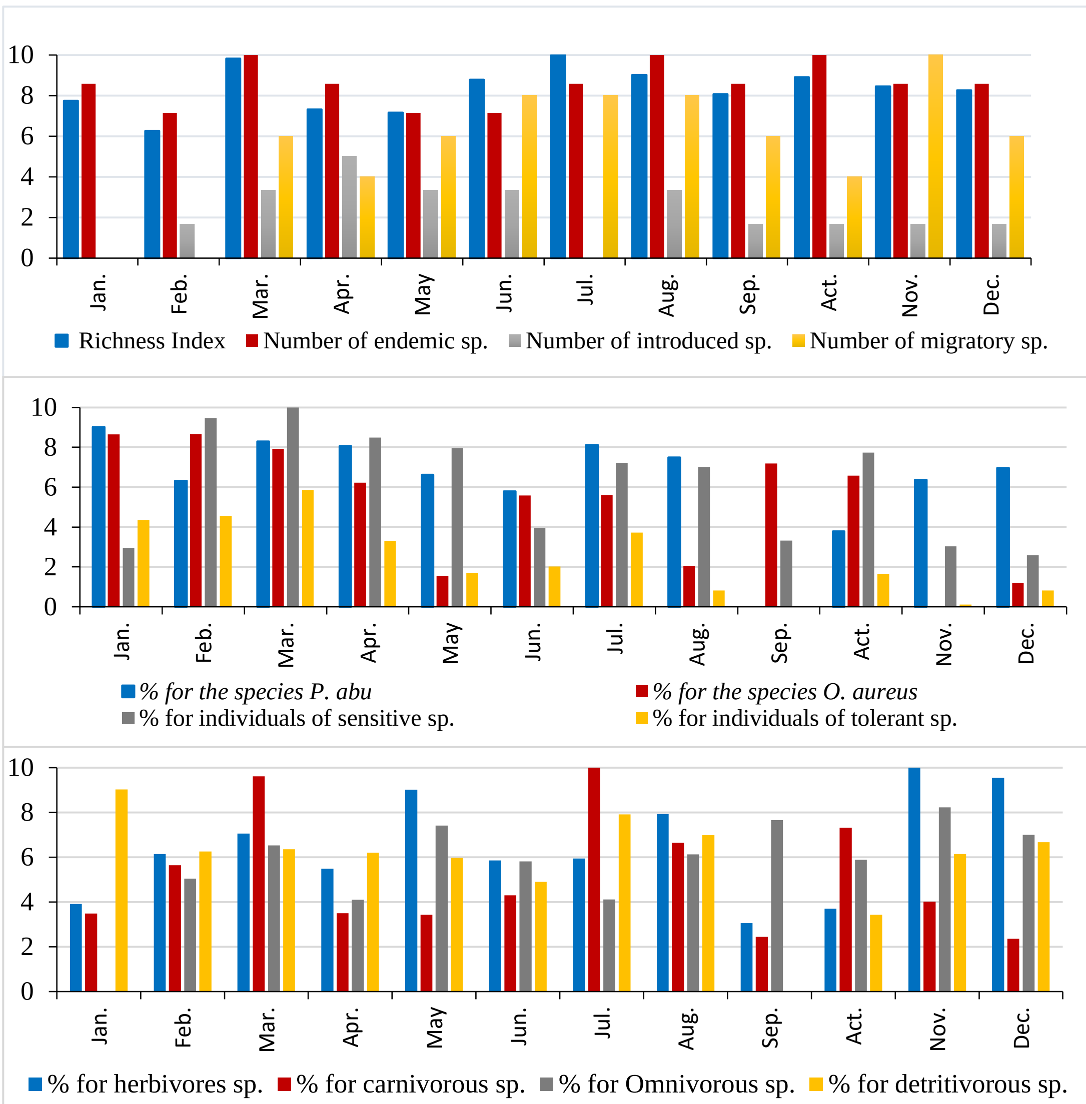

Fig. 6. Monthly values of integrated biologigal index unit scores during the study period

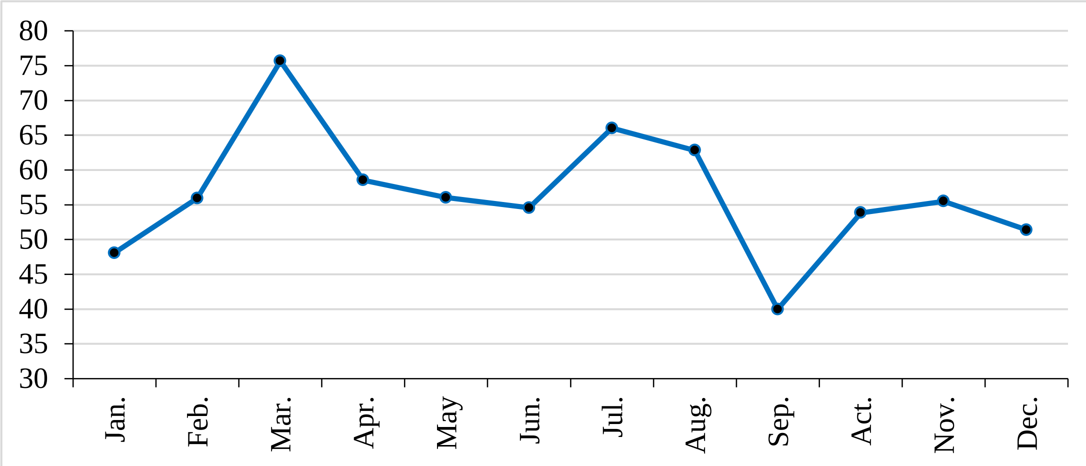

Fig. 7. Monthly integrated biological index values

The primary metrics were selected based on their applicability and stability across previous studies and are consistently associated with environmental degradation. The twelve metrics used represent the best characteristics of the assemblages and are affected by patterns of environmental decomposition or regression in the Euphrates River in the study area. This is revealed through the correlation values between those metrics and the final result of the value of the evidence. The study in this paper demonstrated that the selected metrics were absolutely associated with the direction of the effect of each metric. That is, the final IBI value was directly affected by six metrics, and the higher the value of the metrics, the higher the final IBI score, which is as follows: richness index r = +0.512; number of endemic species r = +0.354; number of migratory species r = +0.260; percentages of sensitive species r = +0.683; percentages of herbivores species r = +0.351; percentages of carnivorous species r = +0.803. The remaining six metrics were inversely related to the final IBI score, and increasing these metrics reduced the final value of the index, which is as follows: number of introduced species, r = -0.297, percentages of individuals of *Planiliza abu* r = -0.629, percentages of individuals of tolerant species r = -0.563, and percentages of members of Omnivorous species r = -0.025, the percentages of individuals of detritivorous species, r = -0.489. Interestingly, the rate of individuals of the type *Oreochromis aureus* showed a weak correlation (r = 0.008), suggesting no significant impact on the direction of the IBI score. This finding highlights the importance of considering the strength of correlations in interpreting the impact of different metrics on the IBI score.

DISCUSSION

The results of the species richness group indicate that the values of the richness index are affected by the number of the endemic and migratory species. This means that the role of the exotic fish in the richness of the fishing area in terms of species abundance, is diminishing. Moreover, the structural characteristics of fish groups at different levels increase our ability to understand ecosystems, which is essential for maintaining aquatic ecosystems. Studies have indicated that local processes and large-scale environmental variables can determine fish population systems **(Hoeinghaus *et al*., 2007)**. In this paper and this species richness group, the unit number of total species proposed has been modified **(Karr, 1981)** into three units, as shown in Table(1). It is advisable to separate the total species into the classifications of species present in the water body to show the extent of the impact of environmental disturbances on each of them, The number of endemic species and families, a measure of biodiversity at the species and family level, also decreases with increasing human disturbance **(Noss, 1990; Ruaro &Gubiani, 2013)**.

Considering the undesirable impact of the introduced species as they affect the local species and their ability to endure compared to the endemic species. The introduced species are often accidentally released from breeding farms or for various purposes. These species can alter the structure of the native populations through competition and predation, and sometimes they eliminate some native species; as a result, IBI should be negatively related to the number of the non-native species present **(Zhu &Chang, 2008)**. The richness index combines diversity and numerical abundance into one measure, which logically indicates the fishing area's richness and compares the variation of its values to determine the best season.

One of the original measures adopted by **Karr*et al*. (1986)** was fish community composition. The tolerant species are a clear indicator of a decline in quality at an ecological level. These species were considered hardy since they could tolerate a variety of environmental conditions. After all, they were widespread in catches and frequently occurred during most fish survey periods. In addition, the sensitive species are susceptible to many types of environmental stress and tend to be absent in the presence of environmental deterioration, such as suspended solids, increased temperatures, sediments, and decreased dissolved oxygen. These species disappear at the beginning of environmental disturbance and are the last to reappear after environmental restoration**(Karr, 1981; Lyons *et al*., 2000)**.

The nutritional composition group includes four food classes and is widely used in many bodies of water. These metrics reflect the trophic dynamics of fish populations and typically use individual adults to define the criteria that finely separate species groups. To assess the disruption to the food web by anthropogenic stressors, divergence is measured from the expected patterns of production and energy consumption resulting from changes in water quality that, in turn, modify the nutritional base of fish populations. Thus, the measures of trophic composition are used to assess changes in ecological processes or functions. The evidence units can then be expanded to include both structural and functional components **(Ganasan &Hughes,1998)**.

For the unit of herbivorous species, it is the basis of the food web and the food pyramid, where the flow of energy in the ecosystem begins, and it supports the nutritional chains at the top; increasing this measure, increases the index values, as it revitalizes the integrity of the environment since it is sensitive to physical and chemical habitat changes that deplete plant communities or disrupt vegetation formation, providing information about the health of primary production at the study site.The impact of increasing the unit of detrital species is negative on the health of the water body since they can tolerate a wide range of abiotic variables and are well adapted to survive in degraded environments

(Magalhaes *et al*., 2002). This unit is designed to measure the change in food supply from the dominance of invertebrates to the dominance of plants and organic residues. Individuals of this species tend to increase under disturbed conditions, and it has been used to assess fish populations in many areas **(Hughes & Oberdorff, 1998)**; increasing this unit affects negatively the final value of the evidence. Carnivorous fishes include species in which adults feed primarily on fish, other vertebrates, or macroinvertebrates, and this measure distinguishes between high and moderate water quality characteristics and tends to decline with environmental disturbance.

Fig. (5) summarizes the principal components analysis, the correlation of the units used in the guide, the strength of each unit's effect, and the percentages of the impact of each of the three vectors used. It can be said that, out of the twelve units in the biointegration guide, there are nine efficient units. In contrast, the three units were less responsive and efficient in being sensitive to surrounding environmental changes. PCA, it is a dimensionality reduction approach by analyzing raw data using the matrix technique, where the eigenvectors of the matrix produce the axes and give the eigenvalues a measure of the level of discrimination present in the data **(Ma & Dai, 2011)**.

These metrics provide robust indicators across a range of levels (e.g., individual, community, and ecosystem) to measure the state of organisms. Biota and characteristics are included in the IBI if they show consistent and predictable responses to human activities **(Kimberling *et al*., 2001)**. The index is a regional indicator for analyzing and monitoring the impact of human disturbance on fish population composition. It does so by comparing the current community composition with that in a reference state, as proposed by **Karr *et al.* (1987)**. This involves comparing the state of the river with a similar river characterized by less human influence and intervention, or comparing historical data for the same water body or nearby bodies.

Therefore, on this basis, we compared the extracted value of the index with the areas near the river. In the Shatt al-Arab River, southeast of the study area, the IBI value reached 67.8% in the study by **Hussain *et al*. (1989)**, and its environment was described as good. Its values decreased significantly in a study by **Younis (2005)** and were described as poor, reaching 18.1%. On the other hand, its condition was restored in the study of **Mohamed *et al*. (2012)** and became 53.8%. While, it reached 45.23% in the study of **Yaseen *et al*. (2018)** and was evaluated on a moderate environmental basis. In a study by **Al-Shammary (2008)** of the Al-Hammar Marsh, located south of the study area, and a study by **Mohamed *etal.*(2008)** in the Al-Hawizeh Marsh, northeast of the study area, as well as a study by **Mohamed and Hussain (2012)** in the eastern Al-Hammar Marsh, and finally a study by **Mohamed (2014)** in the Al-Chibaish Marsh, north of the study area, the index values for those areas were 40.8, 41.5, 42.6, and 45.6%, respectively.

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