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Application of GIS technique in the studies on fish assemblages in Shatt Al-Arab River, Basrah, Iraq

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Abstract:

The present study has examined the spatiotemporal varieties of the demographics of the Shatt Al-Arab River fishes and their relation to some ecological components. The aim is to forecast these groups in the unexplored parts of the waterway with an emphasis on environmental indices of diversity. Three sites in the river were selected as an observation and study of these species, which lasted from March 2019 to February 2020, the study dealt with factors affecting fishes, as Water Temperature (WT), Dissolved Oxygen (DO), Potential Hydrogen Ion (pH), Salinity (Sal), and Transparency (Tra). Gill nets, cast nets, hooks, and hand nets were adopted to collecting fish. The results indicated that the fish population comprises 60 species representing 13 orders, 28 families, all species belonged to Osteichthyes except for one (Carcharhinus leucas) which belonged to Chondrichthyes. Cyprinidae is the prevalent family embraced by nine species. WT (12.1- 33.4°C) has a considerable influence on the total number of species and individuals to the north of the watercourse. However, salinity (0.9- 8.7 mg/L) was regarded as the essential impact on the composition, distribution, and abundance of species in the rest sites. Planiliza abu was the most abundant species attaining 20.21%, followed by Oreochromis aureus (16.41%), and Carassius auratus ranked (15.92%), the dominance (D3) value was 52.54%. The results of the current study showed that most of the diversity index values are considered a moderate status. On the other hand, the majority of the richness index values are viewed as semi disturbed status in all stations, while most of the values recorded of the evenness index are deemed as semi-balanced status. The application of GIS technique by using the ordinary kriging method showed high efficiency in the Shatt Al-Arab River. Therefore, this technique can be employed in environmental studies of fishes.

Keywords: Fish diversity, Canonical Correspondence Analysis (CCA), Ecological factors, Spatial analysis

Introduction:

Shatt Al-Arab River is affected by the tidal phenomenon, so it is considered a critical transitional zone. Fish in these environments has physiological abilities that enable them to react to changes in salinity [1-3]. Over the past decade, Shatt Al-Arab River has suffered from serious problems. The decrease of flow from the Tigris and Euphrates rivers is the most important one, that is because the hydrological ventures, developed in neighboring nations and control of water sources coming across borders, led to the penetration of salt water wedge from the bay to the rivulet stream. Another reason is the deterioration of water quality due to exposure to industrial, agricultural waste, and sewage, which leads to the decay of the aquatic environment, and the entry, spread of invasive and alien species, all these problems produced a change in the composition of fish populations [4-7]. However, the principal dangers to biodiversity are the ecological variances, contamination, natural changes, and overexploit of the stocks, besides obtrusive species [8-10].

Geographic information systems technics provided an integrated environment to view and analyze data obtained from the satellite image, field measurements, and laboratory analyses, by presenting the information in form layers, output maps for each factor of fish assemblage and perform spatial analysis and predict the value of any investigated factors in any site of the river [6]. Moreover, the spatial interpolation tool is typically utilized in the survey of fish ecology, particularly for the development of ecological system models. Nonetheless, the level of autocorrelation in some cases restricts the utilization of the common kriging addition strategy. In this way, conventional kriging is a strongly suggested strategy if the information is spatially autocorrelated [11].

Several studies pointed out that the fish population structure of Shatt Al-Arab River was concerned with the fish ecology, especially recording and classifying the existing fish [5, 6, 12, 13, and 14]. There is a large number of global studies that applied GIS in the study of aquatic animals and fish, in particular. However, there are no local studies that depend on GIS except for Lazem [6] and Mohamad *et al*. [13].

Due to the event of waves of torrents and floods that are sweeping Iraq and neighboring countries (which did not occur since three decades), this causes the spring floods, consequently the increased drainage of water from the tributaries of the Shatt Al-Arab River. The main goal of the current study is to recognize the variations of the Spatio-temporal pattern of fish gathering and its relationship to some environmental factors in Shatt Al-Arab River during this period.

Study area

Shatt Al-Arab River is one of the most important rivers in Iraq, formed by a confluence of the Tigris and Euphrates Rivers nearby Al-Qurna town, south of Iraq [15]. Tidal current penetrating from the Arabian Gulf twice a day influences the River. It runs about 204 km and alters in width, from 250m at Al-Qurna to more than 2 km at Al-Fao city [16].

To perform the present study, three stations were determined (Fig. 1). The first station was in coordination with geographic location (47°28'32.2" E 30°58'29.7" N) located to the north of the river nearby the point of contact for Al-Swaib channel, Shatt Al-Arab River. The second station (47°46'21.3" E 30°34'48.9" N) was near Sindbad island, and the third (48°05'21.9" E 30°26'57.4" N) was near Om Al-Rasas island.

From each station, fish samples were collected every month from March (2019) to February (2020) by various fishing methods that rely on fish species, including; gill nets, cast nets, hooks, and hand nets.

The multi-measure device (WTW Multi 350i) was measured; water temperatures, DO, pH, and salinity. Moreover, a Secchi disk counted the transparency of water. Besides the GPS waypoints were registered for spatial reference at each location by using Garmin eTrex 22x Rugged Handheld GPS Navigator.

Materials and Methods:

Methodology and Materials:

Fish specimens were counted and classified by several authors [17-20]. We used the fish classification system in Eschmeyer's Catalog in Table 1 according to the evolutionary level of fish families. Fish assemblage analysis (in the three sites) was carried out by the following processes and indices: relative abundance [21], domination (D3) [22]. Fish species were split (according to their occurrence in the monthly samples) into three categories [23]: resident (common) species (nine -12 months), seasonal (six-eight months), and occasional (one - five months). The CANOCO program (version 4.5) was utilized for: measuring the ecological indices (diversity, evenness, and richness), doing the multivariate analysis of data among months, and plotting CCA ordination. The SPSS program (version 20) was used for all statistical analyses of the collected data. However, the ArcGIS 10.4.1 program was applied by the spatial analysis method. The Spatio-temporal variability of fish data was predicted by the ordinary kriging interpolation method, with a spherical semivariogram model using the spatial analyst tool in ArcGIS. The ordinary kriging method is the most basic way of kriging interpolation, which allows for applying a statistical model that included autocorrelation. Moreover, using these interpolated values, photomap layers for each parameter were developed, which show the spatial distribution pattern of these fish across the river. Furthermore, a buffer tool was used to display the map features more clearly for the study area.

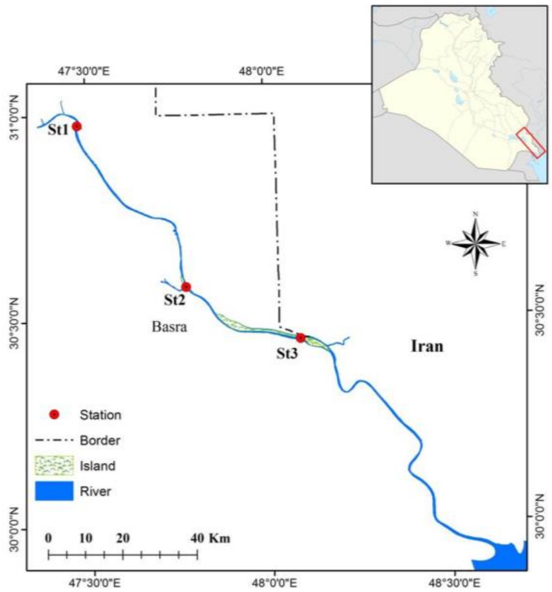

Figure 1. Map of the Shatt Al-Arab River showing the studied stations

Results:

Ecological factors

Monthly fluctuations in water temperature, dissolved oxygen, pH, salinity, and transparency in the Shatt Al-Arab River have shown in Fig. 2. Insignificant disparity among the stations in all the studied factors (WT, DO, pH, and Tra; $p > 0.05$; F= 0.052, 0.122, 0.72 and 0.015 respectively), except for one in salinity values ($p < 0.05$, F= 18.62), were found among station 3 and the other locations. WT fluctuated from 12.1°C in January at station 2 to 33.4°C in August at station 3. DO values varied from 6.4 mg/L in August at station 1 to 10.5 mg/L in December at the same station. Restricted vacillations in pH ranged from 7.03 in March at station 2 to 8.2 in June and August at stations 1 and 2, respectively. Salinity values differ from 0.9 mg/L in March at station 1 to 8.7 mg/L in January at station 3. Water transparency shifted from 15 cm in April at station 3 to 79 cm in December in the same region.

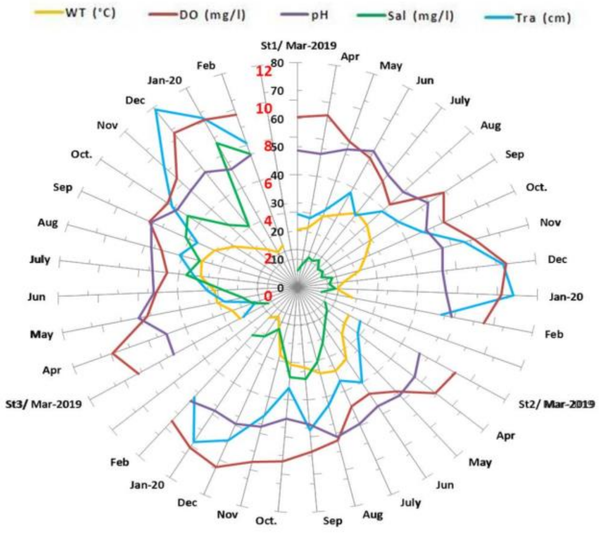

Figure 2. Monthly variations in water temperature, dissolved oxygen, pH, salinity, and transparency at the examined stations.

Fish population structure

Sixty fish species gathered from the investigated sites in the Shatt Al-Arab River belong to 13 orders, 28 families; 12 of them are exotic, 19 freshwater, and 29 marines. All species relate to Osteichthyes except for one (*Carcharhinus leucas*) impute to Chondrichthyes. The dominant family was Cyprinidae, which comprised nine species, followed by Xenocyprididae, Leuciscidae, and Mugilidae (four species). However, five families take part by three species for each (Engraulidae, Cichlidae, Sillaginidae, Sparidae, and Sciaenidae), five families formed by two specimens (Clupeidae, Gobiidae, Carangidae, Poeciliidae, and Aphaniidae), and the rest families represented by one species each (Table 1).

Table 1. Fish orders, families, genera, and species collected from the study stations.

Order	Family	Species
Carcharhiniformes	Carcharhinidae	*Carcharhinus leucas*
Clupeiformes	Clupeidae	*Nematalosa nasus*
		Tenualosa ilisha
	Engraulidae	*Thryssa dussumieri*
		Thryssa vitrirostris
		Thryssa whiteheadi
	Pristigasteridae	*Ilisha compressa*
Cypriniformes	Cyprinidae	*Arabibarbus grypus*
		Carasobarbus luteus
		Carassius auratus
		Cyprinion kais
		Cyprinus carpio
		Garra rufa
		Luciobarbus kersin
		Luciobarbus xanthopterus
		Mesopotamichthys sharpeyi
	Xenocyprididae	*Ctenopharyngodon idella*
		Hemiculter leucisculus
		Hypophthalmichthys molitrix
		Hypophthalmichthys nobilis
	Leuciscidae	*Acanthobrama marmid*
		Alburnus caeruleus
		Alburnus sellal
		Leuciscus vorax
Siluriformes	Bagridae	*Mystus pelusius*
	Siluridae	*Silurus triostegus*
	Heteropneustidae	*Heteropneustes fossilis*
Gobiiformes	Gobiidae	*Bathygobius fuscus*
		Boleophthalmus dussumieri
Synbranchiformes	Mastacembelidae	*Mastacembelus mastacembelus*
Carangiformes	Polynemidae	*Eleutheronema tetradactylum*
	Soleidae	*Brachirus orientalis*
	Cynoglossidae	*Cynoglossus arel*
	Carangidae	*Alepes vari*
		Scomberoides commersonnianus
Cichliformes	Cichlidae	*Oreochromis aureus*
		Oreochromis niloticus
		Coptodon zillii
Cyprinodontiformes	Poeciliidae	*Gambusia holbrooki*
		Poicilia latipinna
	Aphaniidae	*Aphanius stoliczkanus*
		Paraphanius mento
Beloniformes	Belonidae	*Strongylura strongylura*

	Hemiramphidae	*Hyporhamphus limbatus*
Mugiliformes	Mugilidae	*Chelon carinatus*
		Planiliza abu
		Planiliza klunzingeri
		Planiliza subviridis
Acanthuriformes	Leiognathidae	*Photopectoralis bindus*
	Scatophagidae	*Scatophagus argus*
Perciformes	Sillaginidae	*Sillago arabica*
		Sillago attenuate
		Sillago sihama
	Sparidae	*Acanthopagrus arabicus*
		Acanthopagrus sheim
		Sparidentex hasta
	Sciaenidae	*Johnius belangerii*
		Johnius dussumieri
		Otolithes ruber
	Platycephalidae	*Platycephalus indicus*

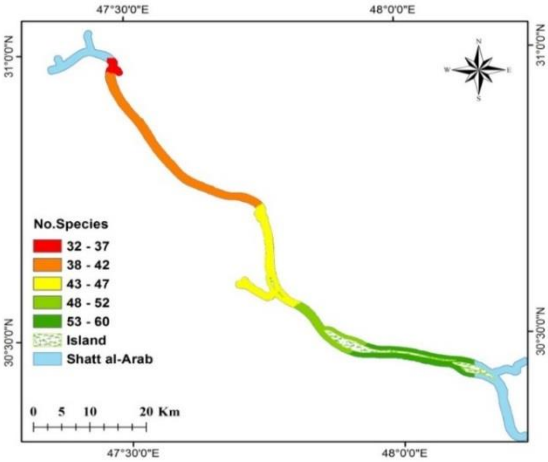

Figure 3. Geographical distribution pattern of the total number of species in the Shatt Al-Arab River.

Fig. 3 reveals that the spatial pattern of the total number of species in Shatt Al-Arab River, with note moral differences (P<0.05, F=2.874), was found between Station 1 and 3. Thirty-six species recorded at station 1, they differed from nine in January to 25 in May. At station 2, Forty-six species found, range from 15 in May to 28 in October. Fifty-five species represented at station 3, which vary from 17 in March to 28 in September. Sixty species did collect from the study site fluctuated from 27 in March and December to 42 in August (Fig.4).

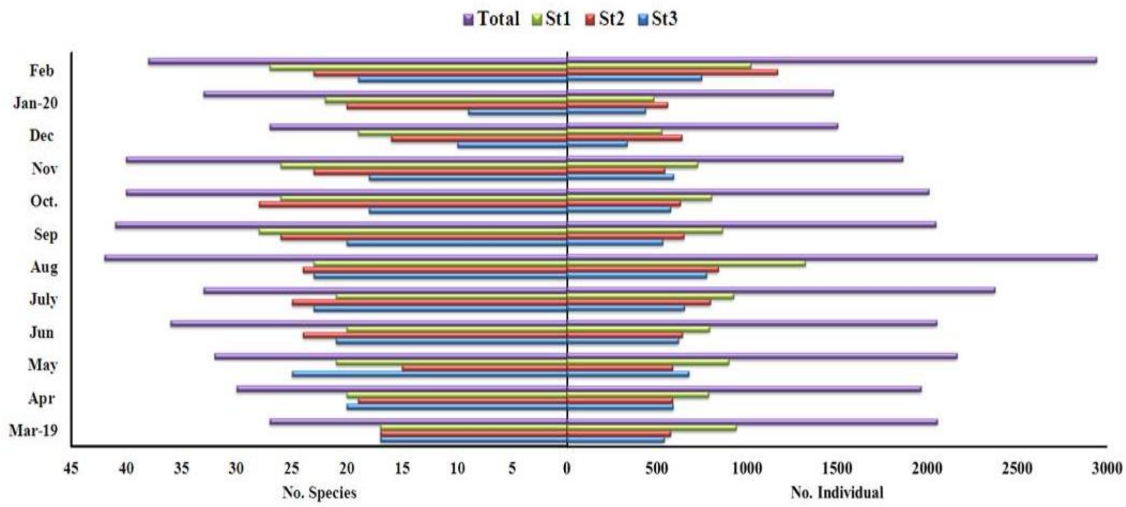

Figure 4. Monthly fluctuations in the No. of species and individuals in the study stations and the total No. in the studied stations.

A total of 25413 fish specimens were captured from the study stations ranged from 1480 in January to 2943 in August. The number of individuals at station 3 emerged to differ significantly (P<0.05, F=6.075) with other stations. An equal of 7086 fish was recorded at station 1, which varied from 336 in December to 777 fish in August. Besides, 8228 fish were caught in station 2, fluctuated from 545 in November to 1170 fish in February. Meanwhile, 10099 fish were registered from station 3, improved from 483 in January to 1325 fish in August (Fig. 4). Fig. 5 illustrated the spatial distribution pattern of the total number of individuals in Shatt Al-Arab River.

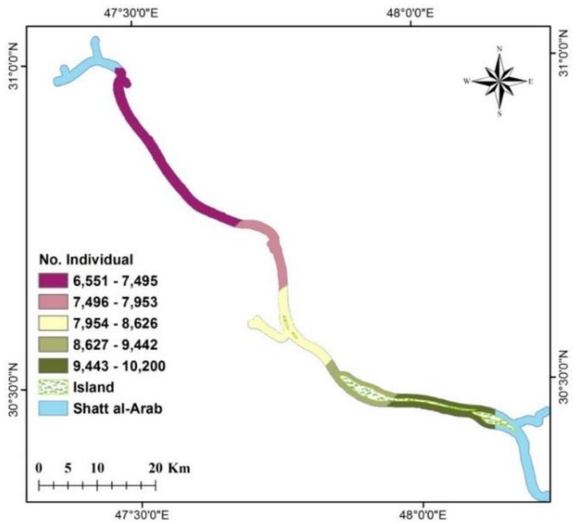

Figure 5. Geographical distribution pattern of the total number of individuals in the Shatt Al-Arab River.

Relative abundance of fish

During the study period, *Planiliza abu* was represented 20.21% as a dominant species in Shatt Al-Arab River. It fluctuated from 10.25% in March to 35.43% in February. *Oreochromis aureus* comprising 16.41% of the gathering changed from 9.54% in June to 27.33% in November. *Carassius auratus* reached 15.92%; its abundance varied from 10.22% in April to 21.89% in July. According to the Dominance index (D3), these three species formed 52.54% of the total number of species in the Shatt Al-Arab River (Table 2).

Table 2. Monthly variations in abundance of fish species collected from the studied stations.

Species	Cod	Site	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Occurrence	Total No.	Abundance	Habitat
Planiliza abu	***Pab***	**1,2,3**	0.10	0.19	0.17	0.19	0.15	0.20	0.18	0.15	0.15	0.34	0.21	0.35	12	5135	**20.21**	**F**
Oreochromis aureus	***Oau***	**1,2,3**	0.14	0.17	0.20	0.10	0.14	0.15	0.19	0.16	0.27	0.21	0.16	0.12	12	4171	**16.41**	**E**
Carassius auratus	***Cau***	**1,2,3**	0.18	0.10	0.21	0.16	0.22	0.14	0.13	0.16	0.17	0.17	0.18	0.12	12	4047	**15.92**	**E**
Coptodon zillii	***Czi***	**1,2,3**	0.12	0.19	0.18	0.13	0.19	0.15	0.15	0.14	0.15	0.13	0.15	0.16	12	3917	15.41	**E**
Tenualosa ilisha	***Til***	**1,2,3**	0.12	0.10	0.09	0.12	0.06	0.05	0.04	0.05	0.01				9	1380	5.43	**M**
Poicilia latipinna	***Pla***	**1,2,3**	0.06	0.05	0.03	0.06	0.04	0.05	0.02	0.03	0.06	0.02	0.05	0.02	12	1038	4.08	**E**
Cyprinus carpio	***Cca***	**1,2,3**	0.07	0.04	0.001	0.08	0.02	0.01	0.02	0.07	0.01	0.03	0.01	0.04	12	848	3.34	**E**
Oreochromis niloticus	***Oni***	**1,2,3**	0.03	0.02	0.01	0.02	0.02	0.01	0.03	0.02	0.03	0.02	0.10	0.04	12	713	2.81	**E**
Planiliza klunzingeri	***Pkl***	**1,2,3**	0.09	0.04	0.003	0.01	0.01	0.03	0.05	0.03	0.01		0.03	0.02	11	665	2.62	**M**
Scatophagus argus	***Sar***	**2,3**		0.003	0.001	0.001		0.08	0.04	0.03			0.003		7	394	1.55	**M**
Alburnus sellal	***Ase***	**1,2,3**	0.01		0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	11	329	1.29	**F**
Acanthopagrus arabicus	***Aar***	**1,2,3**	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.005	0.002	0.01	12	323	1.27	**M**
Thryssa whiteheadi	***Twh***	**1,2,3**		0.00	0.01	0.02	0.01	0.02	0.04	0.02	0.01	0.002	0.001	0.01	11	281	1.11	**M**
Planiliza subviridis	***Psu***	**1,2,3**	0.01	0.01	0.00	0.01	0.01	0.003	0.01	0.02	0.003	0.003	0.04	0.01	12	249	0.98	**M**
Acanthobrama marmid	***Ama***	**1,2,3**	0.00	0.002	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.01	12	223	0.88	**F**
Thryssa vitrirostris	***Tve***	**1,2,3**		0.01	0.01	0.003	0.01	0.02	0.01	0.01	0.02	0.005		0.002	10	222	0.87	**M**
Carasobarbus luteus	***Clu***	**1,2,3**	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		0.002	0.01	11	205	0.81	**F**
Gambusia holbrooki	***Gho***	**1,2,3**	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		0.003	11	196	0.77	**E**
Aphanius stoliczkanus	***Ast***	**1,2,3**	0.003	0.003	0.001	0.02	0.01	0.01	0.01	0.01	0.004		0.01	0.002	11	178	0.70	**F**

Leuciscus vorax	***Lvo***	**1,2,3**	0.004	0.004	0.01	0.01	0.004	0.00	0.01	0.01	0.01	0.01	0.005	0.0003	12	154	0.61	**F**
Hemiculter leucisculus	***Hle***	**1,2,3**	0.001	0.01	0.003	0.002	0.001	0.01	0.003	0.002	0.005	0.00	0.001	0.004	12	90	0.35	**E**
Silurus triostegus	***Str***	**1,2,3**	0.01	0.005	0.004	0.001	0.0004	0.002	0.004	0.003	0.003	0.01	0.001	0.004	12	85	0.33	**F**
Thryssa dussumieri	***Tdu***	**2,3**						0.004	0.003	0.003	0.01	0.001	0.01	0.003	7	68	0.27	**M**
Sparidentex hasta	***Sha***	**2,3**					0.003	0.002	0.002	0.01		0.001	0.002	0.01	7	60	0.24	**M**
Paraphanius mento	***Pme***	**1,2,3**	0.001	0.002	0.01	0.001		0.002	0.003	0.001	0.01	0.001	0.003	0.001	11	57	0.22	**F**
Acanthopagrus sheim	***Ash***	**3**				0.001		0.002					0.01	0.01	4	37	0.15	**M**
Bathygobius fuscus	***Bfu***	**2,3**	0.001	0.002		0.0005	0.001	0.001	0.002	0.002	0.003		0.003	0.002	10	37	0.15	**F**
Boleophthalmus dussumieri	***Bdu***	**2,3**		0.001		0.001		0.001	0.01	0.001	0.002	0.001		0.000	8	28	0.11	**F**
Chelon carinatus	***Ccar***	**2,3**									0.005	0.005	0.003	0.002	4	28	0.11	**M**
Sillago sihama	***Ssi***	**2,3**					0.002	0.0003	0.001	0.003	0.001	0.005	0.002	0.001	8	28	0.11	**M**
Hyporhamphus limbatus	***Hli***	**1,2**	0.001	0.002	0.001		0.001	0.002	0.003					0.002	7	27	0.11	**M**
Photopectoralis bindus	***Pbi***	**2,3**					0.001	0.001	0.001		0.003	0.001	0.003		6	20	0.08	**M**
Garra rufa	***Gru***	**1**			0.001	0.001		0.001	0.002	0.0005				0.002	6	18	0.07	**F**
Nematalosa nasus	***Nna***	**1,2,3**		0.002		0.004	0.001		0.001						4	17	0.07	**M**
Mesopotamichthys sharpeyi	***Msh***	**1,2,3**			0.001	0.001		0.001		0.002	0.002	0.001	0.001		7	16	0.06	**F**
Ctenopharyngodon idella	***Cid***	**1,2,3**	0.0005		0.001	0.0005	0.001	0.001	0.001	0.0005	0.001			0.001	9	14	0.06	**E**
Heteropneustes fossilis	***Hfo***	**1,2,3**		0.001	0.001	0.0005		0.001	0.0005		0.001			0.001	7	11	0.04	**E**
Hypophthalmichthys molitrix	***Hmo***	**1,2,3**	0.001	0.001			0.0004	0.001		0.001		0.001	0.001		7	11	0.04	**E**
Brachirus orientalis	***Bor***	**3**						0.002	0.001		0.001				3	10	0.04	**M**
Mystus pelusius	***Mpe***	**1,2,3**			0.001	0.001	0.001		0.0005	0.0005	0.001				6	10	0.04	**F**
Cyprinion kais	***Ska***	**1,2**				0.0005		0.001	0.001		0.002				4	8	0.03	**F**
Mastacembelus mastacembelus	***Mma***	**1,2,3**	0.0005		0.0005	0.0005		0.0003	0.0005	0.0005	0.001			0.0003	8	8	0.03	**F**
Alburnus caeruleus	***Aca***	**1**				0.001	0.0004		0.001		0.001				4	7	0.03	**F**
Luciobarbus xanthopterus	***Lxa***	**1,2,3**			0.0005		0.001			0.0005	0.001			0.0003	5	6	0.02	**F**
Arabibarbus grypus	***Agr***	**2,3**	0.0005	0.001	0.0005			0.0003			0.001				5	5	0.02	**F**
Luciobarbus kersin	***Lke***	**1,2**						0.0003		0.0005			0.001	0.001	4	5	0.02	**F**
Hypophthalmichthys nobilis	***Hno***	**1,2,3**		0.001				0.0003	0.0005						3	4	0.02	**E**
Platycephalus indicus	***Pin***	**3**									0.001		0.001	0.001	3	4	0.02	**M**
Johnius dussumieri	***Jdu***	**3**												0.001	1	3	0.01	**M**
Sillago arabica	***Sara***	**2,3**								0.001			0.001		2	3	0.01	**M**

Sillago attenuate	***Sat***	**2,3**									0.002				1	3	0.01	**M**
Alepes vari	***Ava***	**3**												0.001	1	2	0.01	**M**
Cynoglossus arel	***Car***	**3**											0.001		1	2	0.01	**M**
Carcharhinus leucas	***Cle***	**2,3**	0.0005			0.0005									2	2	0.01	**M**
Eleutheronema tetradactylum	***Ete***	**3**								0.001					1	2	0.01	**M**
Ilisha compressa	***Ico***	**3**								0.001					1	2	0.01	**M**
Johnius belangerii	***Jbe***	**3**										0.001			1	2	0.01	**M**
Otolithes ruber	***Oru***	**3**							0.001						1	2	0.01	**M**
Scomberoides commersonnianus	***Sco***	**3**								0.001					1	2	0.01	**M**
Strongylura strongylura	***Sst***	**3**					0.004								1	1	0.04	**M**
Number of Individuals			**2058**	**1967**	**2166**	**2054**	**2376**	**2943**	**2049**	**2010**	**1866**	**1503**	**1480**	**2941**	**Total-individuals**			**25413**
Number of Species			**27**	**30**	**32**	**36**	**33**	**42**	**41**	**40**	**40**	**27**	**33**	**38**	**Total-species**			**60**

E= Exotic F= Freshwater M= Marine

Fish species occurrence

Depending on their frequency in the monthly samples, species existing in Shatt Al-Arab River are classified into three groups (Table 3): Common species, represented by 24 species, 13 of them appeared throughout the study period. The common species formed 40% of the whole number consist of native, marine, and exotic species. Thirteen fish species were recognized as Seasonal species, three of their presence in eight months. This group formed 21.67% of the total number of collected species. Finally, 23 species designated as Occasional two of them did represent in five months. Subsequently, Occasional classes reached 38.33% of the whole abundance of species (Fig. 6).

Table 3. Fish species Categorization according to their occurrence in the study area.

Category	No. Sp.	Species				
Common (9-12 months)	24	*A. arabicus*	*A. marmid*	*A. sellal*	*A. stoliczkanus*	*B. fuscus*
		C. auratus	*C. carpio*	*C. idella*	*C. luteus*	*C. zillii*
		G. holbrooki	*H. leucisculus*	*L. vorax*	*O. aureus*	*O. niloticus*
		P. abu	*P. klunzingeri*	*P. latipinna*	*P. mento*	*P. subviridis*
		S. triostegus	*T. ilisha*	*T. vetrirostris*	*T. whiteheadi*	
Seasonal (6-8 months)	13	*B. dussumieri*	*G. rufa*	*H. fossilis*	*H. limbatus*	*H. molitrix*
		M. mastacembelus	*M. pelusius*	*M. sharpeyi*	*P. bindus*	*S. argus*
		S. hasta	*S. sihama*	*T. dussumieri*		
Occasional (1-5 months)	23	*A. caeruleus*	*A. grypus*	*A. sheim*	*A. vari*	*B. orientalis*
		C. arel	*C. carinatus*	*C. kais*	*C. leucas*	*E. tetradactylum*
		H. nobilis	*I. compressa*	*J. belangerii*	*J. dussumieri*	*L. kersin*
		L. xanthopterus	*N. nasus*	*O. ruber*	*P. indicus*	*S. arabica*
		S. attenuata	*S. commersonnianus*	*S. strongylura*		

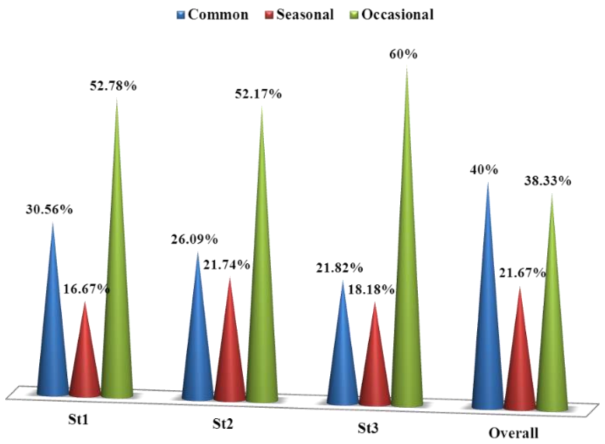

Figure 6. Percentages of fish categories in the study sites with the overall sample during investigation period.

Fig. 7 explains the spatial distribution pattern of the total number of freshwater species in Shatt Al-Arab River. Sixteen species listed in station 1 varied from three in January to 11 in May and August. Seventeen species at station 2 ranged from three in May to 10 in September and October. In station 3, fifteen species were found, the change from five in March and December to 10 in May.

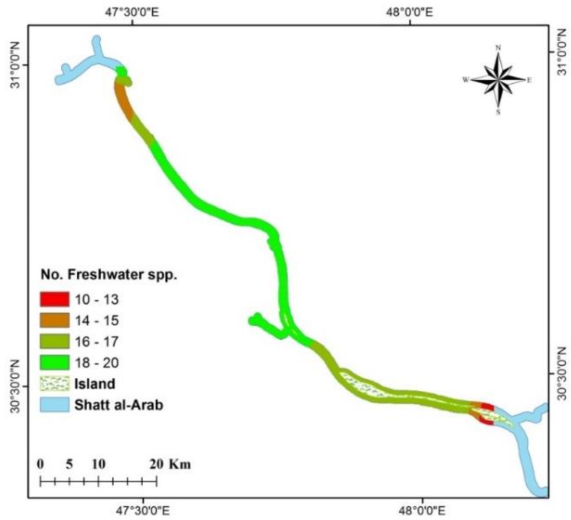

Figure 7. The pattern of the total number of freshwater species in the Shatt Al-Arab River.

The number of alien species was equal in all locations reaching 12 species. They fluctuated from six in December and January to 10 in August at station 1. The minimum number (7) in station 2 appeared in five months, namely March, April. June, January, and February. While the highest number (9) in July and September. Finally, five exotics recorded in October, November, and January at station 3 increased to nine in April and February (Fig. 8).

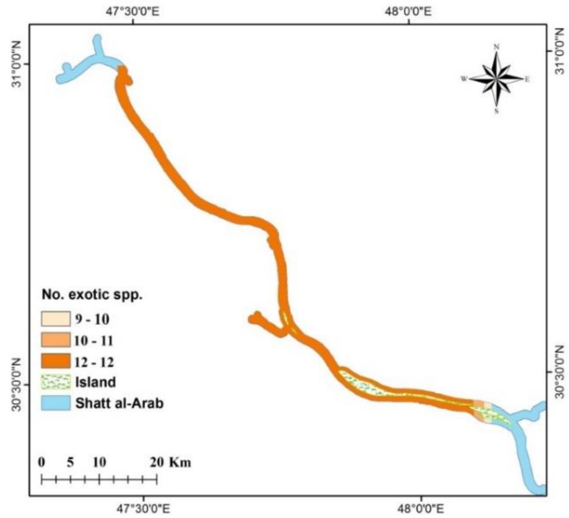

Figure 8. The pattern of the total number of exotic species in the Shatt Al-Arab River.

The geographical distribution pattern of the total number of marine species in Shatt Al-Arab River during the study period is shown in Fig. 9. The lowest number (8) registered in station 1 varied from one in November to six in May and July. Seventeen marine fish in station 2 ranged from two in March to 10 in October. Whereas the highest marine species number was 28 detected in station 3, change from five in March to May, to 12 in August to November and January.

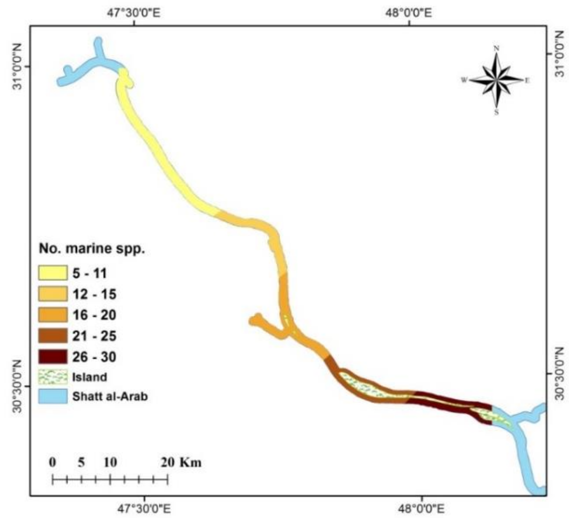

Figure 9. The pattern of the total number of marine species in the Shatt Al-Arab River.

Indices of fish diversity

Monthly fluctuations in ecological indices at the station (1) are illustrated in Fig. 10. The diversity index varied from 1.84 in December to 2.27 in July. The richness index differed from 2.2 in January to 3.22 in May, and the evenness index alternated from 0.66 in May to 0.86 in January. Moreover, at station 2 diversity index ranged from 1.65 in December to 2.52 in October. The richness index fluctuated from

2.71 in May to 3.33 in October, and the evenness index changed from 0.59 in December to 0.78 in January (Fig 11). Meanwhile, at station 3, the diversity index increased from 1.94 in February to 2.62 in September. The richness index ranged from 2.83 in March to 3.33 in September. Also, the evenness index varies from 0.59 in February to 0.79 in June (Fig 12).

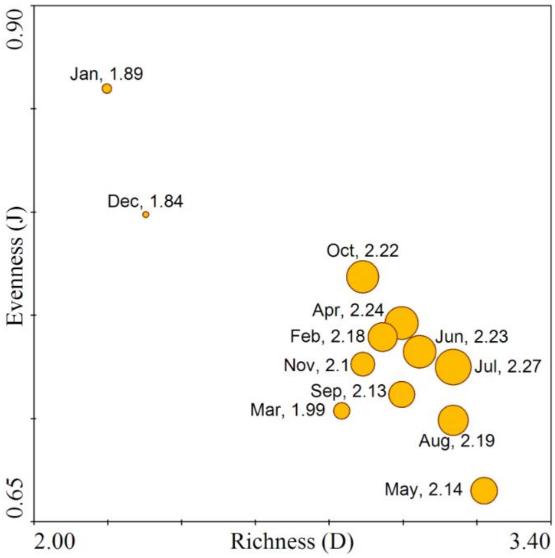

Figure 10. The Plot values of diversity, richness, and evenness indices at Station 1.

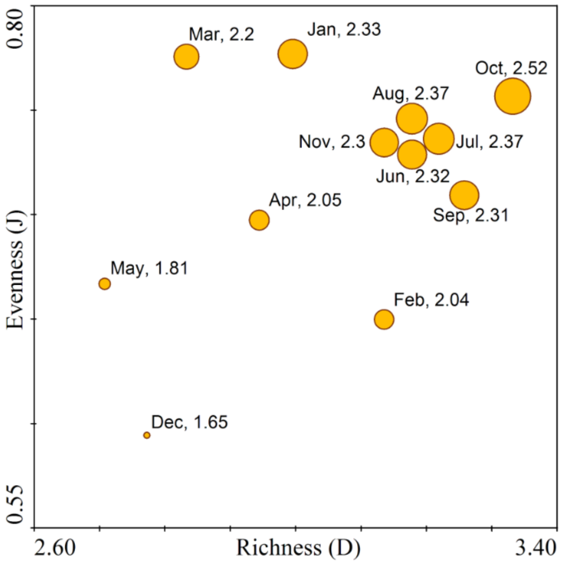

Figure 11. The Plot values of diversity, richness, and evenness indices at Station 2.

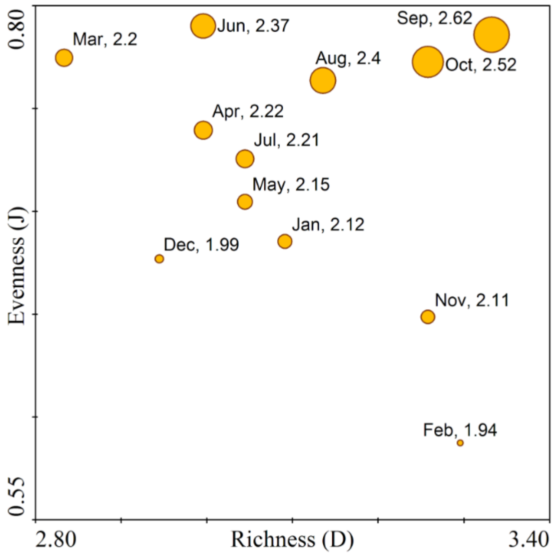

Figure 12. The Plot values of diversity, richness, and evenness indices at Station 3.

Multivariate analysis

The canonical correspondence analysis (CCA) ordination plots epitomized the relationships among the available fish species, individuals, and the ecological elements in the survey sites. In station 1, water temperature was a greater influence factor on the total number of species and individuals compare with other agents (Fig. 13). It was a strong positive correlation with an abundance of species (r= 0.81) and individuals (r= 0.52). However, transparency was a powerful negative correlation with the total number of species (r= -0.76) and individuals (r= -0.44). Salinity (In station 2) was the main impact factor on the total number of species (r= 0.82), followed by water temperature (r= 0.57). On the other hand, pH was the most affective agent (r= 0.64) on the total number of individuals compared with other factors (Fig. 14). However, in station 3 salinity was the greater impact factor (r= 0.74) followed by transparency (r= 0.43). While water temperature was a greater influenced agent (r= 0.57) than others on the number of individuals (Fig. 15).

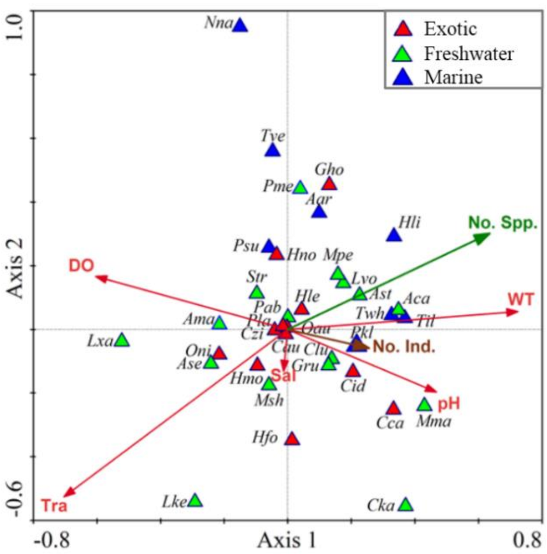

Figure 13. CCA ordination plot presenting the relationship among fish species, individuals, and ecological factors at station 1 (Sp. codes as in Table 2).

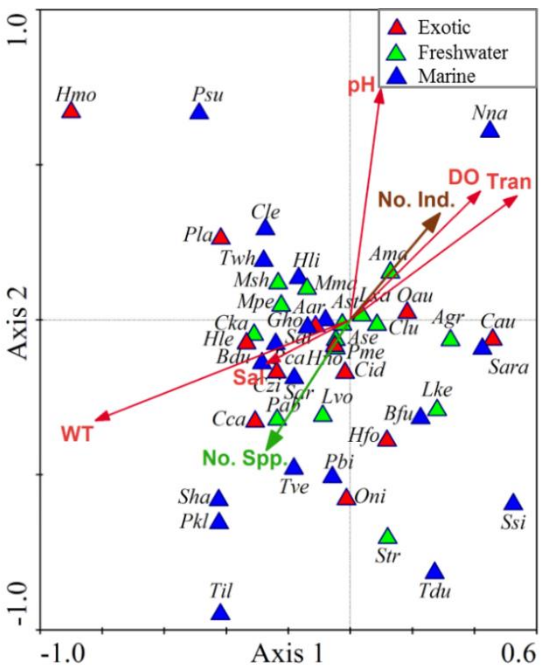

Figure 14. CCA ordination plot presenting the relationship among fish species, individuals, and ecological factors at station 2 (Sp. codes as in Table 2).

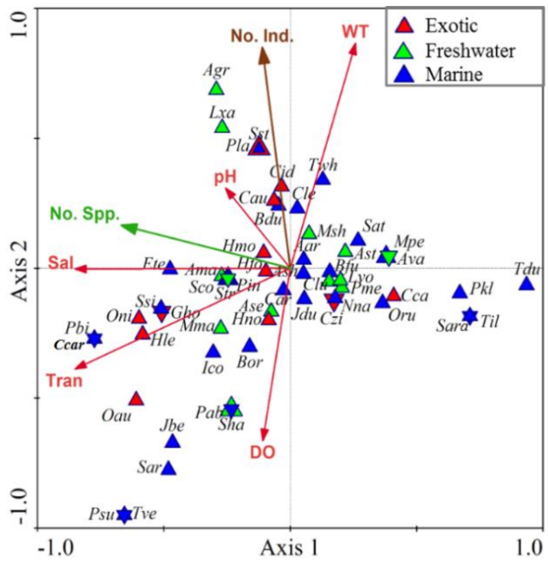

Figure 15. CCA ordination plot presenting the relationship among fish species, individuals, and ecological factors at station 3 (Sp. codes as in Table 2).

Discussion:

Interestingly, the capacity of some fish species to modify to diverse ecological conditions [24]. *P. abu* is considered a native species for a long-time in this area [18]. Likewise, this enabled *P. abu* to prevail in Shatt Al-Arab River in this study, which appeared in all study periods. This result does not coincide with most late studies (during the past decade) which indicate other species' dominance [5, 6, 13, and 14]. As these studies showed, the abundance of species is impressed by aquatic environmental changes. Due to the overfishing, the spread of some invasive species, and lack of water levels lead to saltwater intrusion from the Arabian Gulf. Therefore, that influenced the presence of resident species such as *P. abu* and the composition of the fish community. Although *O. aureus* was registered for the first time (in 2009) in Iraq [25], it managed to adapt to all environments and compete with local species. However, it ranked the second abundance in this study, this is consistent with the study of Mohamed and Abood [26], which indicated that it is one of the dominant species in Shatt Al-Arab River. One of the most important reasons for the widespread of this species is the high tolerance to various environmental conditions [27] and the reproductive activity throughout the year (This applies to other species that belong to the Cichlidae family). Moreover, *C. auratus* is an alien species apparition in water bodies in the early nineties [28], also adapted to prevailing environmental conditions and spread rapidly. Consequently, it ranks third in this study in all locations, which concurs with the conclusions of most previous studies that confirmed the dominance of this species in Shatt Al-Arab River as [6 and 14]. Schiphouwer *et al.* [29] mentioned, invasive species have different life capabilities, which enabled them to expand their spread to affect the composition of the fish community through competition, predation, and interference. That is the main reason for the sharp decrease in the density of the native species. They were recorded with greater abundance in previous studies, that attribute to the reduction of water levels due to the establishment of many dams on the Tigris and Euphrates rivers in Turkey [30], which lead to a reduce the flood seasons. That is a vital factor in the revival of areas for the reproduction of native species (freshwater species). A great abundance of alien species, overfishing, forbidden fishing methods, and catching fish in the breeding times contributed to a low population density of native species.

Interestingly, the spatial analysis results of the number of fish species, individuals in Figures [3, 5, 7, 8, and 9] showed a high ability to predict the expected values in the unexamined areas of the river based on the data recorded in the studied location. That helps tremendously in predicting the status of the fish community in the short and long term, diversity conservation, ecosystem, and the rational management of rivers. It also makes it easier for researchers to work and reduces the effort and time spent on rivers environmental survey. However, the spatial interpolation by the ordinary kriging method showed high efficiency in Shatt al-Arab River, as it does not contain barriers that prevent the movement and spread of fishes. Thus, this technique can be highly employed in environmental studies of fish.

Despite the appearance of 24 species in most of the months of the study (common species), the species that formed a relative abundance of more than 1% did not exceed nine species, including five exotics, five marines, and two freshwater species. The reason may refer to the change of fish community nature because of the rising of alien species number dwelling in Shatt Al-Arab River.

Noticeably, results showed an increase in the portion of marine species in fish populations, which enter the river for reproduction, feeding, or nursery. This aspect coincides with most researchers as Roberts *et al.* [31], Mohamed *et al.* [32], and Kindong *et al.* [33]. Marine species are penetrating the middle and lower reaches of Shatt Al-Arab River, and their numeral reduces towards the upper reaches. Likewise, it predominates in station three formed 50.9% (28 species), the usually dominant species was *Tenualosa ilisha*, which penetrates the river to breeding when the rise of temperature.

As specified by Jorgensen *et al.* [34] and Hussain *et al.* [35], most diversity values recorded (in this study) from the sites can be considered moderate status, rare and poor status at stations 1, 2, and 3 (especially in December). Fish diversity values less than two were recorded in all sites which may be ascribed to changes in environmental conditions in some months that affect the numbers and types of fish. There were slight variations in the values of the richness index recorded in this study, considered as semi disturbed in all stations. By contrast, most of the evenness values state recorded in Shatt Al-Arab River was deemed as semi-balanced, despite the rare ones in balance status from station 1 in January. Indeed, most evenness values ranged between 0.59 and 0.79, indicate the absence of dominance.

Water temperature is a principal factor in controlling the distribution and abundance of living organisms and impacts the physical properties of water. Through the CCA plots, we can observe (at station 1) that water temperature was the prime variable that influences the fish community structure. That agrees with the findings of Lazem and Attee [36] in their studies as concluding that water temperature has the main effect on the presence of fish in freshwater. Likewise, Kim *et al.* [37], Walden *et al.* [38], and Liu *et al.* [39] pointed out that plankton, algae, and invertebrates thrived with the rise of temperature, providing an important food source in the water body, which encourages the attraction of fish species and increases their numerical density. In contrast, salinity is the main factor that affected the composition of fish at station 2 and 3, as promotes to excess the entry of marine fish. That is evident by the rise of the number of species in these two sites compared to the first site. So, salinity is considered the prime variable of the spatial distribution of fishes. Despite the significant increase in water drained in Shatt Al-Arab River stream during the study period, which did not occur for many years ago (40), the salinity values did ascend in some months, especially in the second and third stations. The reason may be attributed to the floods that wash the soil and Agricultural lands, then mix with the water coming to the river.

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Author's declaration:

- Conflicts of Interest: None.
- I hereby confirm that all the Figures and Tables in the manuscript are mine. Besides, the Figures

and images, which are not mine, have been given the permission for re-publication attached with the manuscript.
- The author has signed an animal welfare statement.
- Ethical Clearance: The project was approved by the local ethical committee in The Open Educational College.

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تطبيق تقنية GIS في دراسات التجمعات السمكية في نهر شط العرب، البصرة، العراق

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قسم العلوم، الكلية التربوية المفتوحة، البصرة، العراق.

الخلاصة:

الهدف الرئيسي من الدراسة الحالية هو التعرف على الاختلافات في الانماط المكانية والزمانية لتجمع الأسماك وعلاقتها ببعض العوامل البيئية في نهر شط العرب، وكذلك التنبؤ بهذه التجمعات في الأجزاء غير المدروسة من المجرى المائي مع التركيز على الدلائل البيئية للتنوع. تم اختيار ثلاثة مواقع في النهر لملاحظة ودراسة هذه الأنواع من مارس 2019 إلى فبراير 2020، وتناولت الدراسة العوامل التي تؤثر على الأسماك كدرجة حرارة الماء والأكسجين المذاب والاس الهيدروجيني والملوحة وشفافية المياه. اختيرت الشباك الخيشومية وشبكة السلية والسنارة والشباك اليدوية لجمع الأسماك. أشارت النتائج إلى أن مجتمع الأسماك تمثل بـ 60 نوعا يمثلون 13 رتبة و28 عائلة تعود جميعها إلى صنف الأسماك العظمية باستثناء نوع واحد (*Carcharhinus leucas*) ينتمي إلى صنف الأسماك الغضروفية. سادت عائلة الشبوطيات على باقي العوائل اذ ضمت تسعة أنواع، وتأثر العدد الكلي للأنواع والأفراد بدرجة الحرارة (12.1- 33.4 °م) بشكل كبير شمال النهر، بينما كان للملوحة (0.9- 8.7 ملغم/ لتر) التأثير الاكبر على وفرة وانتشار وتركيبة الأنواع في باقي المواقع. سادت سمكة الخشني *Planiliza abu* على باقي الأنواع بوفرة بلغت 20.21%، يليها النوع *Oreochromis aureus* (16.41%)، ثم سمكة الكرسين *Carassius auratus* (15.92%)، وبلغت قيمة دليل السيادة 53.54%. سجلت معظم قيم دليل التنوع حالة معتدلة، ومن جانب أخر فإن غالبية قيم دليل الغنى تعتبر شبه مضطربة في جميع المحطات بينما كانت القيم الإجمالية المسجلة لدليل التكافؤ بحالة شبه متوازنة. أظهر تطبيق تقنية نظم المعلومات الجغرافية باستخدام طريقة الكريجين العادية كفاءة عالية في شط العرب. لذلك، يمكن استخدام هذه التقنية في الدراسات البيئية للأسماك.

الكلمات المفتاحية: تنوع الاسماك، تحليل المراسلات القويم CCA، العوامل البيئية، التحليل المكاني.