IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 10, Issue 8 Ver. II (August 2017), PP 50-57
www.iosrjournals.org

Dispersal of the exotic fish in the Shatt Al-Arab River, Iraq

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Abstract: *The dispersion of the exotic fish in the Shatt Al-Arab River, Iraq was described. Fish were sampled monthly from three sites using different fishing gears from November 2015 to October 2016. Variations among sites in water temperature were not statistically significant, but salinity showed a spatial gradient along the length of the river. The overall values of salinity in the three sites were 1.2, 2.5 and 9.1‰, respectively. Twelve exotic species were collected from upper site, 11 species from middle sites and four species from lower site belonged to four families, namely Cyprinidae, Cichlidae, Poeciliidae and Heteropneutidae. The general trend was a decrease of exotic fish abundance from upper site to lower site. The most abundant exotic species in the river were C. auratus, comprising 13.2% of the total catch, O. aureus (12.6%) and C. zillii (8.2%). The diversity index of exotic species in the river ranged from 1.07 to 1.55 and the richness index from 1.07 to 1.16, whereas the evenness index varied from 0.49 to 0.71. The study revealed that the fish assemblage of the Shatt Al-Arab River was clearly shifted in the percents of exotic and marine species and the dominancy species compared with the previous status as a result of the decline in rate of discharge of freshwater during the recent years.*

Key Words*: Fish assemblage, exotic fish species, salt intrusion, Shatt Al-Arab River, Iraq*

Date of Submission: 14-08-2017 Date of acceptance: 25-08-2017

I. Introduction

An introduced species (exotic) is any species intentionally or accidentally transported and released by man outside its present range, also the exotic organisms introduced in one country may find their way to the neighboring countries (Kottelat and Whitten, 1996; Kumar, 2000).

The work of Coad (1996) can be considered as the first work on the exotic fish of the Tigris and Euphrates rivers and their tributaries flow through Turkey, Syria, Iraq and Iran. He reported that at least10 exotic species have been established in the Iraqi waters namely, common carp (*Cyprinus carpio*), stinging catfish (*Heteropneustes fossilis*), mosquito fish (*Gambusia holbrooki*), silver carp (*Hypophthalmichthys molitrix*), silver crucian carp (*Carassius auratus*), grass carp (*Ctenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis)*, redbelly tilapias (*Coptodon* (*Tilapia*) *zilli*), the Nile tilapia (*Oreochromis niloticus*) and the blue tilapia (*Oreochromis aureus*).

During the last decades, several exotic fish have been brought into Iraqi waters as biological control agents (i.e., *G. holbrooki*; *H. fossilis*; *C. idella*) or for aquaculture (i.e., *C. carpio*; *H. molitrix*; *H. nobilis*). Others which are majority, such as *C. auratus*, *C. sublimes*, *H. leucisculus*, *O. aureus*, *C. zilli*, *O. niloticus* and *P. latipinna* have been invaded Iraqi waters by different ways (Jawad, 2003; Coad, 2010, Mohamed and Abood, 2016). Also, Jawad (2003) reviewed the history of introduced (exotic) fish in that time; *C. carpio*, *H. fossilis*, *G. holbrooki*, *H. molitrix* and their affects on the native freshwater fish of Iraq. Since then, a number of other exotic fish species such as *C. auratus*, the sharpbelly (*Hemiculter leucisculus*), *C. idella*, *H. nobilis*, the sailfin molly (*Poecilia latipinna*), *C. zilli*, *O. niloticus*, *O. aureus* and the hemri (*Carasobarbus sublimes*) have been introduced or translocated and some of them are well established in different natural water bodies of Iraq (Al-Shammaa *et al*. 2002; Coad and Hussain, 2007; Salih, 2007; Coad, 2017; Mohamed, *et al.*, 2017).

The Shatt Al-Arab River forms from the confluence of the Tigris and Euphrates rivers at Qurna town northern Basrah Governorate, and flows to southeastern direction towards the Arabian Gulf. It is about 204 km, and varies in width from 250 m at Qurna to more than 1,500 m at the estuary. The River is affected by the tidal current of the Gulf (Al-Lami, 2009). The river plays an important role supplying water to urban centers, agriculture, and supporting commercial and subsistence fisheries. The River suffered from massive regression in water quality related to the decline in rates of discharge from the Tigris and the Euphrates Rivers (Al-Mahmood, *et al*., 2015) as a result of several hydrological projects constructed in the riparian countries (Partow, 2001), and the diversion of the Karun River into Iranian terrene (Hameed and Aljorany 2011). The average rate of discharge in the upstream of the Shatt-Al-Arab River was declined from 207m^3/s during 1977-1978 to 60m^3/s during 2014 (Alaidani, 2014). Several studies have been supportive of the deterioration of the Shatt al-Arab water quality which attributed to reduced freshwater discharges from Tigris and Euphrates Rivers and the

negative impact of salt intrusion from the Arabian Gulf over the past decade (Brandimarte, *et al.*, 2015; Moyel and Hussain, 2015; Yaseen, *et al*., 2016).

Although several studies have been carried out on the ichthyofauna and the fish assemblage structure of Shatt Al-Arab River, no separate study has been done on the exotic species in the river (Al-Nasiri and Shamsul-Hoda, 1975; Al-Hassan, *et al.*, 1989; Hussain *et al.*, 1989, 1995, 1999; Mohamed *et al.*, 2012, 2015). Therefore, the objective of this study is to describe the spatial and temporal variations in exotic fish structure in the Shatt Al-Arab River, Iraq during 2016-2017.

II. Materials and Methods

Samples were collected monthly from three sites on the Shatt Al-Arab River during November 2015- October 2016. Site 1 (upstream) is located near Al-Dair Bridge, site 2 (midstream) is sited in Abu Al-Khasib district and site 3 (downstream) is located north Al-Fao town (Fig. 1).

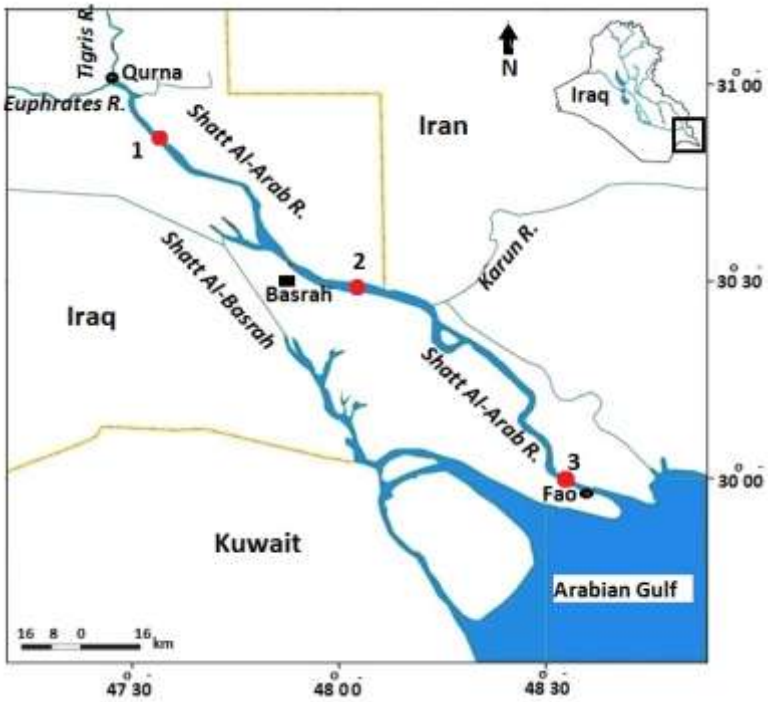

Fig. 1. Map of Shatt Al-Arab with locations of study sites.

Water temperature and salinity were measured *in situ* at each sites using WTW portable instrument model 556 MPS. The monthly rate of discharge in the upstream of the river was obtained from Water Resources Directorate in Basrah. Fish samples were regularly collected from each site by using gill nets (200 m length with 15- 35 mm mesh size), cast net (9 m diameter with 15x15 mm mesh size) and electro-fishing by generator engine (provides 300-400V and 10A). Fish were counted and classified to species following Carpenter *et al.* (1997), Durand, *et al.* (2012) and Coad (2017).

The relative abundance was calculated from the equation n_i /N×100 (Odum, 1970), where n_i is the number of individuals of 'ith' species and $N= \Sigma n_i$. Shannon-Weaver index of diversity was obtained by the following equation $H' = -\Sigma p_i \, lnp_i$ (Shannon and Weaver, 1949), where $p_i = n_i/N$; n_i is the number of individuals of 'i'th species and $N= \Sigma n_i$. The species richness was calculated using the equation $D= (S-1)/ln\ N$ (Margalef, 1968), where S is the number of species, N is the total number of individuals. The evenness is $J= H'$/lnS (Pielou, 1977), where H' is the diversity and S is the number of species. All statistical analyses were performed using the SPSS version 16 for Windows.

III. Results

Environmental parameters

Monthly changes in water temperature, salinity and discharge rate in the three sites of Shatt Al-Arab River are presented in Figures 2 and 3. Values of water temperature varied from 13.6^{o}C in January to 34.5^{o}C in July in upper site, from 14.1^{o}C in January to 34.6^{o}C in August in middle site and from 12 3^{o}C in January to 35.3^{o}C in August in lower site (Fig. 2). Variations among sites in water temperature were not statistically significant (F= 0.74, P>0.05).

Salinity showed a spatial gradient along the length of the river (Fig. 3). The values fluctuated from 0.5‰ in October to 2.2‰ in January in upper site, and in middle site from 1.6‰ in May to 4.6‰ in November, whereas in lower site from 0.5‰ in May to 25.9‰ in August. Significant differences in salinity (F= 8.08, P>0.05) was detected between the sites. The overall values of salinity in the three sites were 1.2, 2.5 and 9.1‰, respectively. While the monthly discharge rate in the north of Shatt Al-Arab River did not show a strong seasonal pattern and the mean values varied from 40.88m³/s in December to 59.75m³/s in March, with overall value was 48.25m³/s (Fig. 3).

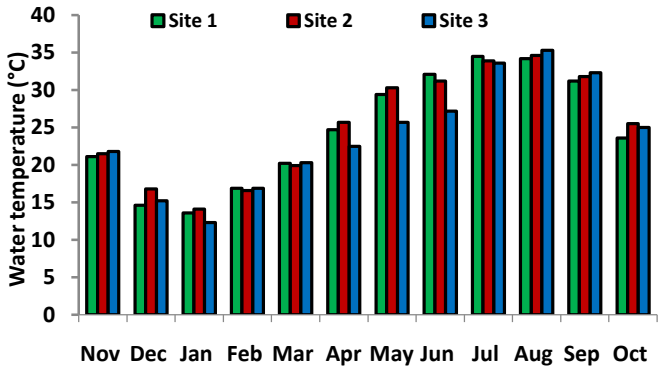

Fig. 2. Monthly variations in water temperature in different sites of Shatt Al-Arab River

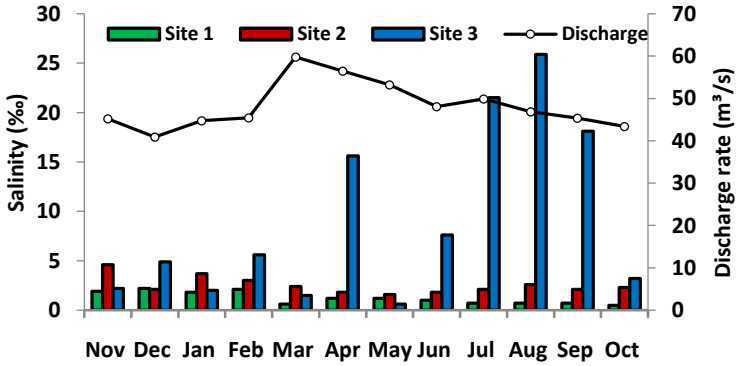

Fig. 3. Monthly variations in salinity and discharge rate in different sites of Shatt Al-Arab River

Spatial and temporal variation in fish composition

During the study, 95,347 fish comprising 50 families, 89 genera and 111 species of bony and cartilaginous fish were captured from the Shatt Al-Arab River during the study. One hundred and eight bony species were composed, 15 of them were native, 83 marine and 13 exotic species. *C. auratus* was the most abundant species constituting 13.24% of the total numbers followed by *O. aureus* (12.58%) and the Klunzinger's mullet, *Planiliza klunzingeri* (10.56%).

The distribution of exotic fish species in different sites of the river was presented in Table 1. The exotic species belonged to four families, namely Cyprinidae (*C. auratus, C. carpio, C. sublimes, H. leucisculus, H. molitrix, C. idella* and *H. nobilis*), Cichlidae (*O. aureus, C. zillii* and *O. niloticus*), Poeciliidae (*P. latipinna* and *G. holbrooki*) and Heteropneutidae (*H. fossilis*). Twelve exotic species were collected from upper site and 11 species from middle sites, and only four species, namely *C. carpio, O. aureus, C. zillii,* and *P. latipinna* were captured from lower site. The Jaccard similarity of exotic species composition between the three sites in the river revealed that the highest similarity level (91.7%) was found between upper and middle sites, indicating that in these areas species composition is the most similar, and weak similarity between site 3 and other two sites, 33.3 and 36.4%, respectively.

Table 1. Exotic fish species distribution in the three sites of the Shatt Al-Arab River. (Present (+), Absent (-), Resident (R), Seasonal (S), Occasional (O))

Family	Fish species	Upper site	Middle site	Lower site	The River
Cyprinidae	*Carassius auratus*	+, R	+, R	-	+, R
	Cyprinus carpio	+, R	+, R	+, O	+, R
	Carasobarbus sublimus	+, R	+, O	-	+, R
	Hemiculter leucisculus	+, R	+, R	-	+, R
	Hypophthalmichthys molitrix	+, O	+, O	-	+, O
	Ctenophryngodon idella	+, O	+, O	-	+, O
	Hypophthalmichthy nobilis	-	+, O	-	+, O
Cichlidae	*Oreochromis aureus*	+, R	+, R	+, S	+, R
	Coptodon zilli	+, R	+, R	+, O	+, R
	Oreochromis niloticus	+, R	+, R	-	+, R
Poeciliidae	*Poecilia latipinna*	+, R	+, R	+, O	+, R
	Gambusia holbrooki	+, O	-	-	+, O
Heteropneutidae	*Heteropneustes fossilis*	+, O	-	-	+, O

Eight exotic species were considered as a resident species and four species as occasional species in upper site (Table 1), where as in middle site, seven species were resident species and four species were considered as occasional. In lower site, one exotic species (*O. aureus*) was considered as a seasonal and three as occasional species. In general, eight exotic species were considered as a resident species and five species as occasional species in the Shatt Al-Arab River.

Spatial and temporal variation in fish abundance

Monthly variations in the relative abundance of the exotic fish in different sites are presented in Table 2. The general trend was a decrease of exotic fish abundance from upper site to lower site. The abundance of the exotic fish in upper site fluctuated from 37.0% in July to 82.3% in March, with an overall value of 62.7% of the total catch in this site. *C. auratus* was the most abundant exotic species comprising 21.5% and ranged from 10.3% in July to 38.8% in May. *O. aureus* was constituted 19.5% and varied from 12.5% in July to 35.0% in May, while *C. zillii* formed 13.0% and changed from 4.5% in May to 22.2% in April. In middle site, the relative abundance of the exotic fish varied from 37.8% in May to 96.9% in February, with a mean value of 59.5% of the total catch in the site. Also, *C. auratus* , *O. aureus* and *C. zillii* were the most abundant species in middle site and constituted 19.7, 19.3 and 12.4%, respectively of the total catch in this site. *C. auratus* varied from 10.3% in July to 38.8% in May, *O. aureus* 7.2% in January to 30.5% in February, while *C. zillii* ranged from 4.1% in July to 24.5% in November. Most the exotic species were absent at the lower site and only four exotic species (*O. aureus*, *C. zillii*, *P. latipinna* and *C. carpio*) were captured from this site. They formed only 0.2% of the total catch in this site, and displayed an irregular pattern (Table 2).

In general, the relative abundance of the exotic fish in the Shatt Al-Arab River varied from 27.3% in August to 71.4% in January, with a mean value of 39.4% of the total catch in the river. *C. auratus* was the most abundant exotic species (13.2%), followed by *O. aureus* (12.6%) and *C. zillii* (8.2%) of the total catch.

Monthly variations in the ecological indices of exotic species in upper, middle sites and Shatt Al-Arab River are given in Figure 4. The general trend was a decrease of exotic species richness from upper site to lower site. In upper site, the diversity index changed from 1.14 in January to 1.60 in March, while the richness index varied from 0.94 in November to 1.27 in June. The evenness index ranged from 0.55 in January to 0.77 in March. In the other hand, the diversity index in middle site fluctuated from 0.82 in January to 1.42 in September and the richness index varied from 0.63 in February to 1.00 in April, whereas the richness index showed values between 0.39 in January and 0.73 in September. The diversity index of exotic species in the river fluctuated from 1.07 in January to 1.55 in August and the richness index varied from 1.07 in March to 1.16 in May, whereas the evenness index ranged from 0.49 in January to 0.71 in August.

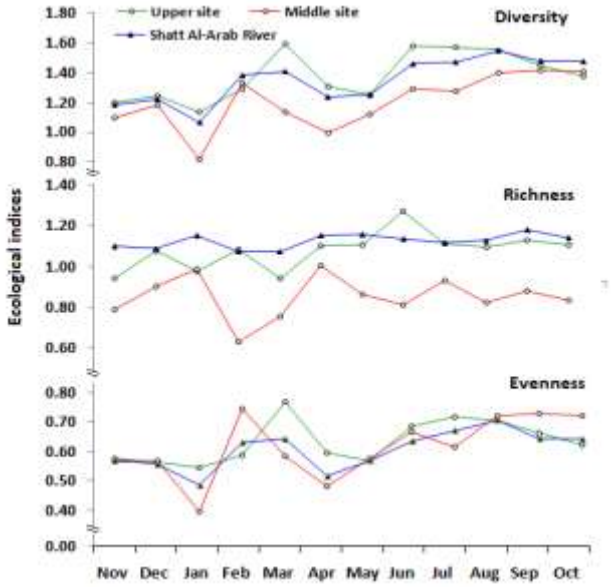

Fig. 4. Monthly variations in the ecological indices of exotic species in Shatt Al-Arab River

Table 2. Monthly variations in relative abundance of exotic species collected from the different sites of Shatt Al-Arab River

Species	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Upper site													
C. auratus	27.22	21.53	30.6	30.75	19.58	16.89	38.79	13.8	10.26	24.44	16.94	15.16	21.488
O. aureus	21.24	35	16.17	22.33	19.73	25.46	12.98	18.37	12.46	12.76	18.27	24.18	19.522
C. zillii	13.71	14.21	20.46	19.42	21.33	22.22	4.47	6.01	4.53	6.44	11.88	20.2	12.985
C. carpio	1.39	3.8	0.11	0.2	0.15	0.15	0.05	5.23	6.47	11.03	6.01	0.53	3.221
C. subliumis	-	0.28	0.76	4.53	0.7	3.48	0.19	3.05	2.42	8.09	0.8	5.13	2.465
H. leucisculus	0.15	0.05	0.16	0.2	14.24	0.19	3.1	0.54	0.46	0.26	0.05	0.14	1.489
P. latipinna	0.23	0.19	0.27	0.44	6.49	0.39	3.48	0.66	0.09	0.26	0.57	0.38	1.031
O. neloticus	0.08	0.19	0.49	0.74	0.1	0.19	0.28	0.29	0.09	0.17	0.09	0.19	0.227
G. holbrooki	-	-	-	-	-	-	1.5	0.37	0.2	-	0.24	-	0.194
H. molitrix	0.15	0.09	-	-	-	-	-	-	-	-	-	-	0.022
C. idella	-	-	-	0.1	-	-	-	0.04	-	-	-	-	0.015
H. fossili	-	-	-	-	-	-	-	-	-	0.04	-	0.1	0.011
Middle Site	-	-	-	-	-	-	-	-	-	-	-	-	-
C. auratus	10.09	23.23	50.52	34.35	24.99	14.8	19.46	26.58	7.22	13.35	9.78	15.09	19.736
O. aureus	21.62	26.77	7.17	30.5	23.3	28.91	11.36	17.26	11.36	19.58	11.5	17.86	19.33
C. zillii	24.5	20.41	12.59	20.35	21.65	4.44	5.99	4.24	4.09	4.94	6.22	11.4	12.428
C. carpio	0.35	0.46	0.17	0.17	0.1	0.23	0.11	10.05	23	15.6	13.62	9.48	6.418
O. neloticus	0.14	0.15	0.06	11.36	0.13	0.09	0.51	0.22	0.2	0.29	0.18	0.21	1.138
P. latipinna	-	0.55	0.23	0.17	0.18	0.42	0.11	0.66	0.15	0.55	0.36	0.42	0.3
H. leucisculus	0.09	0.09	0.17	-	0.03	0.23	0.25	0.15	0.3	0.48	0.05	0.04	0.155
C. idella	-	-	0.12	-	-	-	-	-	-	-	-	-	0.006
H. nobilis	0.03	-	-	-	-	0.05	-	-	-	-	-	-	0.006
C. sublimis	-	-	-	-	-	-	-	-	0.02	-	-	-	0.003
H. molitrix	-	0.03	-	-	-	-	-	-	-	-	-	-	0.003
Lower site	-	-	-	-	-	-	-	-	-	-	-	-	-
O. aureus	-	0.35	0.39	-	-	0.51	0.03	0.05	0.39	-	-	0.12	0.124
C. zillii	-	0.15	0.28	-	-	-	-	-	0.17	0.19	-	0.03	0.056
P. latipinna	-	-	-	-	-	-	-	-	0.03	-	-	-	0.003
C. carpio	-	-	-	-	-		0.21	-	-	-	-	-	0.018

Relation between exotic species and environmental variables

The general patterns of the relationships between the relative abundance of exotic species and water temperature, salinity and water discharge rate in different sites of the River are displayed in Figure 5. The abundance of exotic species showed significantly negatively association with water temperature in the upper and middle sites (r= - 0.766 and - 0.765, $p < 0.05$, respectively), while showed positive correlations with salinity in these sites (r= 0.418 and 0.388, $p < 0.05$, respectively). The abundance of exotic species in site 3 exhibited weak negative and positive correlations with water temperature and salinity, respectively. The abundance of exotic species showed very weak correlation with water discharge rate in all sites.

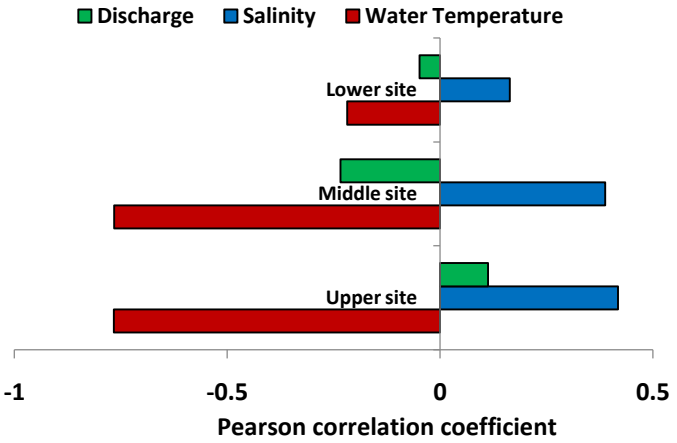

Fig. 5. The correlations between the relative abundance of exotic species and ecological factors in different sites of Shatt Al-Arab River

IV. Discussion

The introduction of alien fishes has caused great changes to the composition of fish fauna by modify local ecological conditions through altering the reproduction, growth and development of native species, as well as hybridization and introducing diseases and parasites (Latini and Petrere, 2004). In the present study, most of the exotic fish species have become acclimatized in the upper and middle sites of the river and one species (*O. aureus*) was considered as a seasonal and three, *C. carpio*, *C. zillii*, and *P. latipinna* as occasional species in the lower site, where fish assemblage was dominated by the marine species. This could be governed by salinity that showed dissimilarity across a longitudinal gradient in the Shatt Al-Arab River, where reached up to 25.9‰ in the lower site. While, there is no effect of river discharge on the abundance of exotic species in the river due to the loss of seasonal changes of the flow from the Tigris River. Al-Shujairi (2013) mentioned that the engineering controls on Tigris and Euphrates rivers have great reduced their seasonality. Various authors have described the longitudinal distribution of salinity in the Shatt Al-Arab River (Al-Hassan *et al.,* 1989; Mohamed *et al.,* 2012; 2015; Abdullah *et al.,* 2016). Prandle (2009) mentioned that the longitudinal salinity variation and the distance of the salinity intrusion are controlled by natural mechanisms, such as tidal range, river flow, geomorphologic features of the estuary, sea level change, among others, as well as human activity interferences, like changes in the drainage basin, drainage channels, water intakes for urban water supply, land use and others.

Also, the study revealed that the fish assemblage was clearly shifted in the percents of exotic and marine species and the dominancy species compared with the previous status. The fish fauna of the river comprised of 83 marine species, 15 native and 13 exotic species. *C. auratus* , *O. aureus* and *P. klunzingeri* were most abundant species, comprising 13.24%, 12.58% and 10.56% of the total catch, respectively. These results were differed from that reported earlier about the fish assemblage in the river. Al-Hassan, *et al.* (1989) mentioned that the fish assemblage in the Shatt Al-Arab River involved 58 fish species, 17 of them were native freshwater, 20 marine and 3 exotic species. Hussain, *et al.* (1995) collected 25 fish species from the middle part of the river, 13 native, 9 marine and 3 exotic species. Also, Hussain *et al.* (1999) recorded 35 fish species from the lower part of the river, 7 native, 26 marine and one exotic species. Mohamed, *et al.* (2012) collected 40 fish species from the river, 9 of them were native, 25 marine and exotic alien species and the most abundant species was *C. auratus* constituting 20.3%, followed by *T. ilisha* (13.3%) and *P. subviridis* (8.7%). Moreover, Mohamed, *et al.* (2015) recorded 58 fish species including 16 native, 32 marine and 10 exotic species during 2011-2012, and the most abundant species were *T. ilisha*, *C. auratus* and *P. klunzingeri* constituting 27.4, 23.7 and 10.6% of the total catch, respectively.

This could be as a result of unfavorable environmental parameters, especially lower discharge rate, higher salinity and the changes in hydrological conditions. Several studies have been supportive of the deterioration of the Shatt Al-Arab water quality which attributed to reduced freshwater discharges from Tigris

and Euphrates Rivers and the negative impact of salt intrusion from the Arabian Gulf (Al-Tawash, *et al.,* 2013; Brandimarte, *et al.*, 2015; Yaseen, *et al*., 2016), as a result of several hydrological projects constructed in the riparian countries (Partow, 2001), and the diversion of the Karun River into Iranian terrene (Hameed and Aljorany 2011).

The number of exotic species was increased considerably comparison with the past findings reported earlier on the river and three new species were recorded in the river namely *C. sublimes*, *O. niloticus* and *H. nobilis*. Al-Hassan, *et al.* (1989) noted only three exotics: *C. carpio*, *G. holbrooki* and *H. fossilis*. Since then, there has been a 4-fold increase in the number of established exotic species in the river. Some exotic species have been intentionally introduced into the Iraqi waters for their commercial (i.e., *C. carpio*; *H. molitrix*; *H. nobilis*) or as biological control agents (i.e., *G. holbrooki*; *H. fossilis*; *C. idella*). Other which are majority, such as *C. auratus*, *C. sublimes*, *H. leucisculus*, *O. aureus*, *C. zilli*, *O. niloticus* and *P. latipinna* are exotic species have been invaded Iraqi waters by different ways (Jawad, 2003; Coad, 2010, Mohamed and Abood, 2016). These results seem to support the hypothesis that exotic species have a greater impact when environmental degradation is high and water quality declines (Godinho and Ferreira, 2000; Olden and Poff, 2003; Lorenzoni, *et al*., 2006; Parks, *et al*., 2014).

V. Conclusions

The study revealed that the fish assemblage of the Shatt Al-Arab River was clearly shifted in the percents of exotic and marine species and the dominancy species compared with the previous status as a result of the decline in rate of discharge of freshwater during the recent years.

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Abdul-Razak M. Mohamed. "Dispersal of the exotic fish in the Shatt Al-Arab River, Iraq." IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS), vol. 10, no. 8, 2017, pp. 50–57.