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THE ECOLOGICAL CONDITION OF THE GARMAT ALI RIVER, IRAQ

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Abstract

The ecological status of the Garmat Ali River was evaluated by using water quality index (WQI) and fish integrated biological index (F-IBI) during the period from November 2015 to October 2016. Water temperature, salinity, transparency and pH were measured from three sites in the river. Fish were captured monthly by different fishing gears. The results revealed that the annual value of water quality index (WQI) of the river was 49.5 which reflect marginal water quality condition. A total 34 fish species were collected, 7 of them were native, 8 exotic and 19 marine species. F-IBI scores were calculated from 15 separate fish assemblage metrics based on the species richness, species composition and trophic guilds. The overall F-IBI value of the river was evaluated to be impaired (F-IBI= 46.5%). The study revealed that the ecological condition of the Garmat Ali River is still deteriorating and this requires improving the quality and quantity of water reaching the river from the Tigris and Euphrates rivers.

Key words: Water quality index (WQI), fish integrated biological index (F-IBI), Garmat Ali River, Iraq

1. Introduction

The human disturbances like pollution, urbanization, agriculture, channel modification, impoundment, and nonnative species introductions have directly and indirectly influenced fish assemblage structure by altering flow regimes, degrading water quality and habitat structure, disrupting energy inputs, shifting biotic interactions (Parks, *et al*., 2014). The IBI is a quantitative measure that integrates a number of biological factors into a single value of ecosystem integrity, and the biological integrity was defined as the ability to support and maintain a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region (Karr, 1999).

The Garmat Ali River was subjected to multiple impacts from hydrological and human activities. After inundation of the southern marshes in 2003, the East Hammar marsh was fed primarily from the Euphrates River and entering the Garmat Ali River then the Shatt Al-Arab River that eventually flows into the Arabian Gulf. So, this river affected by the water from the Euphrates and tidal current of the Gulf through the Shatt Al-Arab River. But, the flow of the Euphrates was diverted away from the north East Hammar marsh during the last years, consequently the water level in the marsh dropped sharply, causing the water salinity higher than before, which led to negatively affected on water quality and quantity of the Garmat Ali River (Al-Tememi, *et al*., 2015).

Moreover, the Shatt Al-Arab 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).

The fish integrated biological index (F-IBI) has been used by several workers to evaluated the fish structure changes in the restored marshes in Iraq (Mohamed, 2014; Mohamed and Hussain, 2014; Mohamed, *et al.*, 2015). Younis, *et al.* (2010) and Mohamed, *et al.* (2012) have been assessed the environment status of the Garmat Ali River using F-IBI from 2003 to 2008. Some other works have been carried out attempting to appraise water quality by using Water Quality Index (WQI) in East Hammar marsh (Al-Saboonchi, *et al.*, 2011, 2014) and Shatt Al-Arab River (Moyel and Hussain, 2015).

Therefore, the objective of this study was to evaluate the environment condition of the Garmat Ali River by applying the water quality index (WQI) and the index of biotic integrity of fish (F-IBI) during 2015-2016.

2. Materials and Methods

This work was carried out on the Garmat Alit Ali River, situated in the north of Basrah city, and is a waterway between the East Hammar marsh and the Shatt Al-Arab River (Fig. 1). It is about 6 km, 280m width and the mean depth is 9m. The river is affected by the tidal current of the Arabian Gulf through the Shatt Al-Arab River. Samples were collected monthly from the three sites on the river during November 2015- October 2016. The first site (1) is located at the junction of the river with Shatt Al-Arab River, whereas the second site (2) is located north Garmat Ali Bridge and the third site (3) is located at the confluence of the river with the East Hammar marsh. The predominant vegetations on the banks were *Phragmites australis,* and *Typha domingensis,* whereas *Ceratophyllum demersum* was dominant in the deeper areas.

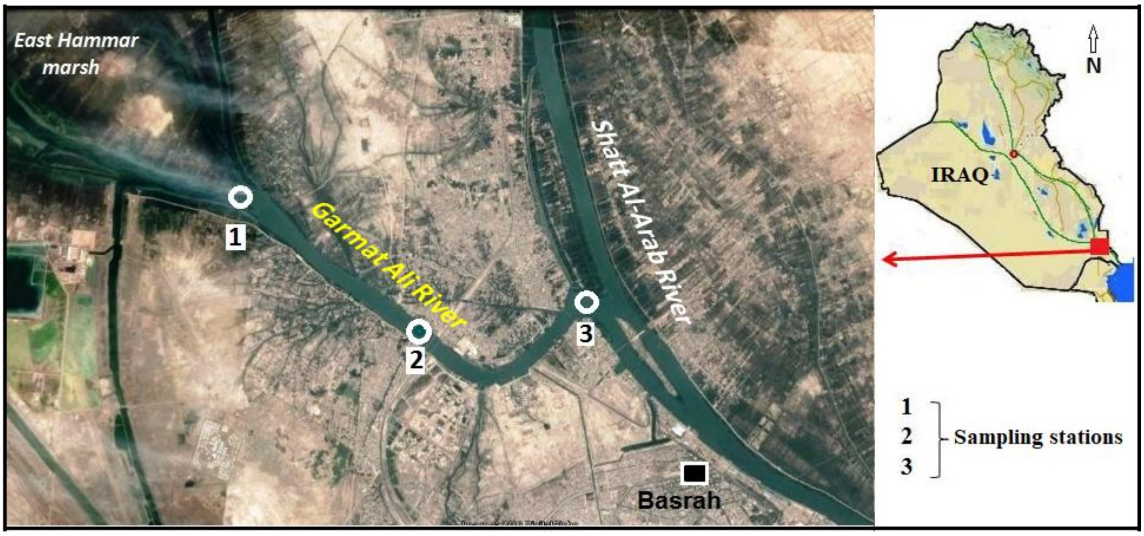

Fig.1. Map of southern of Iraq showing the sampling sites in the Garmat Ali River

Fish sampling was carried out from each site using seine net (140 m long with a 36mm mesh size), fixed gill nets (120 m long with 2.5 cm to 10 cm mesh size) and electro- fishing gear (provides 300-400V, 3–5 A). Fishes were counted and classified to species following Carpenter *et al.* (1997), Durand, *et al.* (2012) and Coad (2017). Fish samples from different species were preserved in a formalin solution (10%) for diets analysis. Various analytical methods were used to analyze stomach contents of the species (Windell and Bowen, 1978). The following factors selected as water quality parameters were measured using the methods described for each factor as follows. Water temperature, salinity and pH were measured *in situ* using YSI portable instrument model 556 MPS. Transparency was evaluated by extinction method using the Secchi disc.

The CCME Water Quality Index (CCME, 2001) was applied for the Garmat Ali River. For this analysis, index scores were determined for air and water temperatures, salinity, transparency and pH. The studies of Younis, *et al.* (2010) and Mohamed, *et al.* (2013) have been adopted as reference studies (historical water quality data) on the water quality of the Garmat Ali River, which represents the period from August 2003 to October 2008. The computed WQI values could be classified as 95-100= excellent; 80-94= good; 65-79 = fair; 45-64 =marginal and 0-44 = poor (CCME, 2001).

The geographic origin (native or marine or exotic) of each fish species were assigned by using a variety of references (Coad, 2017; Mohamed and Abood, 2017). Fifteen metrics were chosen to calculate the fish integrated biological index depending on species richness, species composition and trophic guilds, most them already applied successfully in other studies (Minn *et al.*, 1994; Belpaire *et al.*, 2000; Younis, *et al.*, 2010; Mohamed and Hussain, 2014; Mohamed *et al.*, 2012). 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. We standardized metrics to score from 0 to 10 by using a technique similar to Minns *et al*. (1994). Scores for metrics that increase with environmental quality were calculated by the formula B x raw score, where B= 10/ highest value. Scores of metrics that increase with decreasing environmental quality were calculated as 1- B x raw score, where B = 10/ highest value. Standardized IBI metrics were summed to obtain an IBI score that varied continuously from 0 to 100 for the river and the month, for each metric. IBI scores are rated as impaired (<60), marginally impaired (60-80) and accepted(>80) (Ganasan and Hughes, 1998; Hughes *et al.*, 2006). All statistical analyses were performed using the SPSS version 16 for Windows.

3. Results

3.1 Ecological factors

Water temperature, salinity, transparency and pH were not significantly differences between the three sampling stations (F= 0.47, 0.81, 0.33 and 0.20, $p \leq 0.05$), respectively. Therefore, the monthly variations in the mean values of these factors in the river are shown in Figure 2. The water temperature in this study varied from the lowest value (14.3°C) which recorded during December to the highest value (32.7°C) recorded during

September, with overall value 23.5. The values of salinity ranged from 1.5‰ in June to 6.0 ‰ in December, with overall value
2.8. Transparency values varied from 17.7 cm in July to 55.0 cm in January, with overall value 29.9. Narrow fluctuation of pH was observed during the study period, with the highest average value of 8.3 was recorded during November and a low of 7.2, with overall value 7.7.

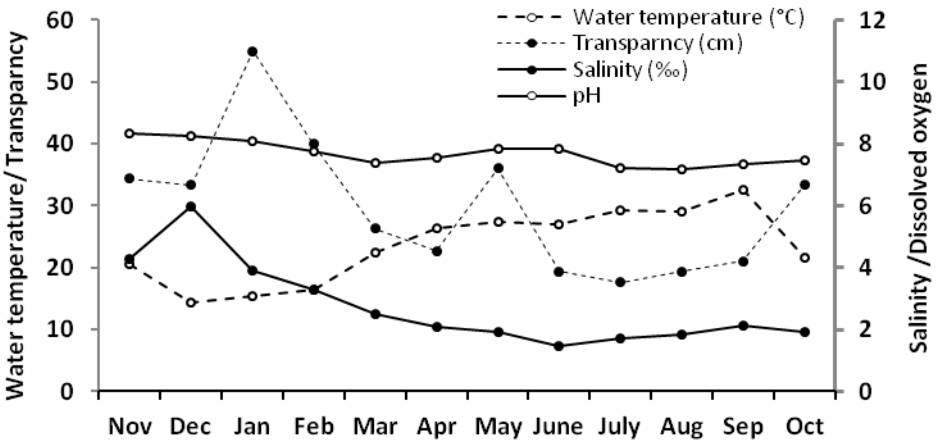

Fig. 2. Monthly variations in the some ecological factors of the Garmat Ali River

3.2 Water Quality Index (WQI)

The descriptive statistics for calculation of CCME-WQI in the Garmat Ali River is mentioned in Table 1. A comparison of the various scopes (F1), frequencies (F2), and amplitudes (F3) values provides a synopsis of how the WQI varied from time to time. The number of tested data was 60 out of which 20 were failed from the historical data. All ecological factors were failed tests (deviated) from their values, except transparency variable. The annual value of water quality index (WQI) of the river during the study period was 49.5 which reflect marginal water quality condition.

Table 1. Summary statistics for calculation of WQI scores in the Garmat Ali River

Term of the Index	Value
Total number of variables	5
Number of failed variables	4
Total numbers of test	60
Number of failed tests	20
Σ excursion	8.09
Nse (normalized sum of excursions)	0.13
F1 (Scope)	80.0
F2 (Frequency)	33.33
F3 (Amplitude)	11.89
CCME-WQI	49.5

3.3 Fish Integrated Biological Index (F-IBI)

The fish species captured from the Garmat Ali River during the study period were arranged according to geographic origin and trophic guilds and are given in Table 2. Thirty four of fish species were captured, eight of them were native, eight exotic and 18 migratory species. The numbers of herbivorous, carnivorous, omnivorous and detritivorous species were 3, 20, 6 and 5, respectively (Table 2).

Monthly variations in the species composition, species richness and trophic guilds metrics used to calculate F-IBI of the Garmat Ali River are presented in Table 3. The native species constituted 20.6% of the total number of species and varied from one species in January to seven species in May, whereas the and changed from four species in August to eight species in June. The migratory species consisted 55.9% of the total number of species and varied from three species in January to 12 species in April. The proportion of native individuals ranged from 0.01% in December to 10.4% in November, whereas the proportion of exotic individuals varied from 8.0% in August to 99.9% in December, and the migratory individuals fluctuated from 0.09% in December to 89.3% in August. The relative proportion of *Planiliza abu* ranged from 0.01% in December to 10.1% in October; *Carassius* *auratus* from 0.28% in December to 45.8% in May and *Poecilia latipinna* from 3.1% in August to 99.0% in June. The relative proportion of tilapia individuals (*Oreochromis aureus, Coptodon zilli* and *Oreochromis niloticus*) fluctuated from

Table 2. Fish species distribution according to IBI metrics in the Garmat Ali River

IBI metrics	**Species**
Native species	*Planiliza abu, Alburnus mossulensis, Acanthobrama marmid, Leuciscus vorax, Silurus triostegus, Aphanius dispar, Carasobarbus luteus* and *Mystus pelusius*
Exotic species	*Poecilia latipinna, Carassius auratus, Oreochromis aureus, Oreochromis niloticus, Coptodon zilli, Hemiculter leucisculus, Cyprinus carpio* and *Gambusia holbrooki*
Migratory species	*Tenualosa ilisha, Thryssa whiteheadi, Thryssa vetrirostris, Hyporhamphus limbatus, Bathygobius fuscus, Planiliza klunzingeri, Photopectoralis bindus , Acanthopagrus arabicus, Sillago sihama , Planiliza subviridis, Boleophthalmus dussumieri, Scatophagus argus, Sillago anttuta, Thryssa dussumieri , Brachirus orientalis , Planiliza carinata, Nematalosa nasus* and *Sillago arabica*
Herbivore species	*O. aureus, C. zilli* and *O. niloticus*
Carnivore species	*T. whiteheadi, T. vetrirostris, H. limbatus, B. fuscus, A. mossulensis, H. leucisculus, A. marmid, L. vorax, G. holbrooki, A. arabicus, S. triostegus, A. dispar, S. sihama, S. argus, S. anttuta, ,M. pelusius, ,T. dussumieri, B. orientalis, S. Arabica* and *P. bindus*
Omnivore species	*P. latipinna, ,C. auratus, C. carpio, ,C. luteus, N. nasus* and *T. ilisha*
Detritivore species	*P. abu, P. klunzingeri, P. subviridis, B. dussumieri, P. carinata*

Table 3. Monthly variations in the fish assemblage metrics used to calculate IBI of the Garmat Ali River (2015-2016).

Metrics	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
No. of native species	4	2	1	2	5	5	7	5	6	5	5	4
No. of exotic species	6	6	5	6	6	7	7	8	6	4	5	6
No. of migratory species	6	6	3	5	10	12	11	8	8	7	9	6
% native individuals	0.6	1.13	0.01	0.04	0.48	0.58	1.55	5.82	3.47	2.7	3.59	10.4
% exotic individuals	73.2	96.2	99.9	98.6	91.5	29.1	86.9	86.9	21.5	8	31.	35. 6
% migratory individuals	26.2	2.7	0.09	1.4	8.0	70.3	11.5	7.3	75	89.3	64.9	54.1
% of *P. abu* individuals	0.28	0.66	0.01	0.03	0.06	0.15	1.38	5.18	2.45	2.58	3.16	10.1
% *P. latipinna* individuals	85.4	87.9	99.0	97.2	85.2	23.7	35.7	50.4	17.6	3.8	25.8	27.1
% of tilapia individuals	0.47	4.41	0.63	1	5.74	4.28	5.18	14. 57	2.25	2.44	4.71	5.05
% of *C. auratus* individuals	1.42	3.34	0.28	0.31	0.44	0.64	45.75	22.0	1.63	1.76	0.99	3.3
% of herbivores individuals	0.23	4.46	0.66	0.95	5.74	4.31	5.18	13.7	2.25	2.48	4.71	5.1
% of detrivores individuals	0.3	0.7	0.007	0.03	0.06	3	1.5	5.2	2.5	2.6	3.2	10.1
% of omnivores individuals	88.9	92.3	99.3	97.8	86.9	26.5	83.6	73.8	82.9	66.8	69.2	65.1
% of carnivores individuals	10.5	2.5	0.03	1.3	7.34	66.2	9.7	6.5	12.3	28.1	22.9	19.7
Species richness	1.78	1.58	0.83	1.19	2.09	2.53	2.51	2.19	2.02	1.67	1.94	1.6

0.47% in December to 14.56% in June. The lowest proportions of herbivorous, carnivorous and detrivorous were 0.66%, 0.03%, 5.7%, 77.2% and 0.01%, respectively in December, while for omnivorous was 26.49% in April. However, the highest proportion of herbivorous was 13.68% in June, carnivorous (66.2%) in April, omnivorous (99.34%) in December and detrivorous (10.1%) in October. The species richness of fish assemblage was varied between 0.83 in January to 2.53 in April.

Monthly variations in F-IBI values of different metrics of fish assemblage in the Garmat Ali River during the study period are plotted in Figures 3-6. IBI score of the marine species fluctuated from 2.5 in December to 10 in April, whereas, the IBI score of the number of native fish species ranged from 1.4 in December to 10 in May. The maximum IBI score of exotic species was 5.0 in August, and dropped to zero during June. IBI score of species richness ranged from 3.3% in January to 10% in May (Fig. 3).

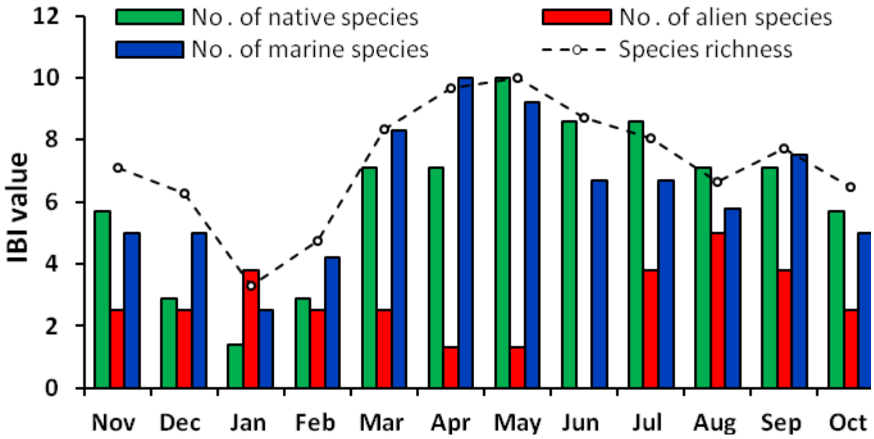

Fig. 3. Monthly variations in some IBI scores metrics in the Garmat Ali River (2015-2016)

The minimum IBI scores of percentages of native and marine individuals were 0.006 and 0.01, respectively recorded in December, whereas the maximum scores was 10 for each one noticed in October and August, respectively. The highest IBI scores of percentage of exotic and *P. latipinna* individuals were 9.2 and 9.87, respectively recorded in August (Fig. 4).

The maximum IBI scores of percentages of *P. abu*, *C. auratus* and tilapia individuals were 9.99, 9.89 and 9.68 recorded in December, February and November, respectively (Fig. 5).

The lowest IBI scores of percentages of herbivorous and carnivorous individuals were 0.17 and 5.0, respectively recorded in November and December, whereas the maximum scores was 10 for each one noticed in June and April, respectively. The maximum IBI scores of percentages of omnivorous and detrivorous individuals were 7.33 and 9.99, respectively observed in April and December (Fig. 6).

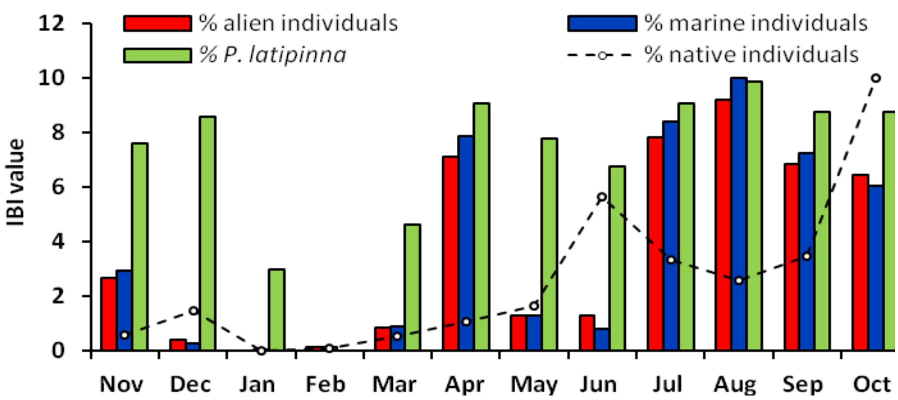

Fig. 4. Monthly variations in some IBI scores metrics in the Garmat Ali River (2015-2016)

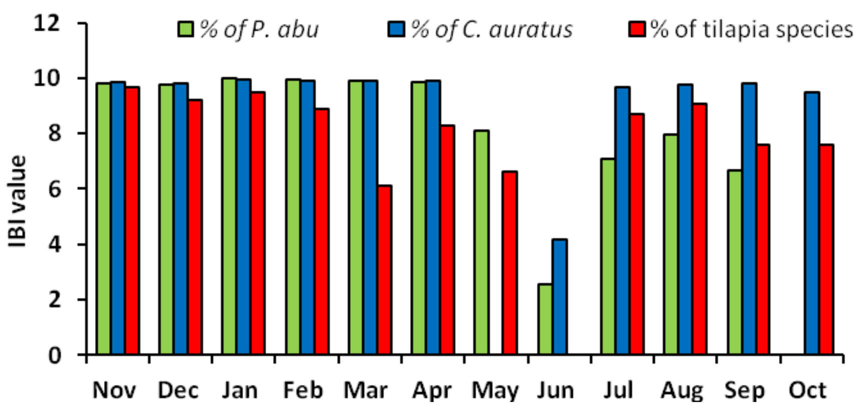

Fig. 5. Monthly variations in some IBI scores metrics in the Garmat Ali River (2015-2016)

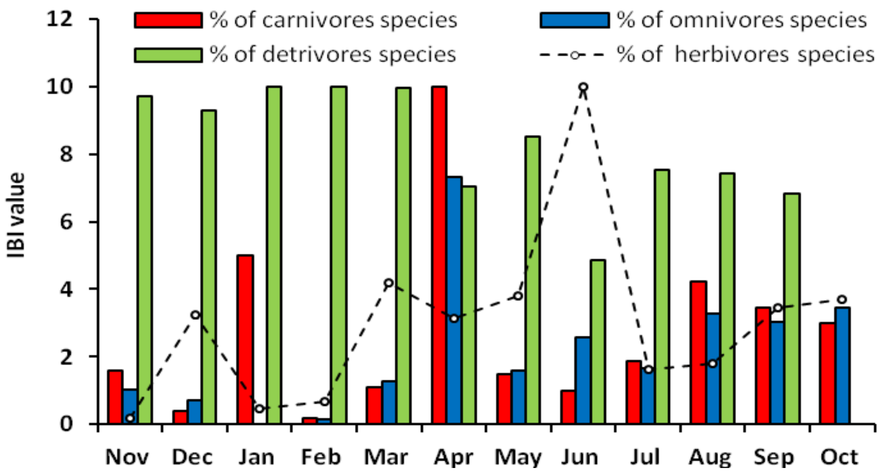

Fig. 6. Monthly variations in some IBI scores metrics in the Garmat Ali River (2015-2016)

Monthly fluctuations in the total F-IBI score of fish assemblage in the river during the study period is shown in Figure 7. The F-IBI values varied from 34.0 in January and classified as impaired to 65.8 in April and considered as marginally impaired. The overall F-IBI value of the river was evaluated to be impaired (F-IBI= 46.5%) during 2015-2016.

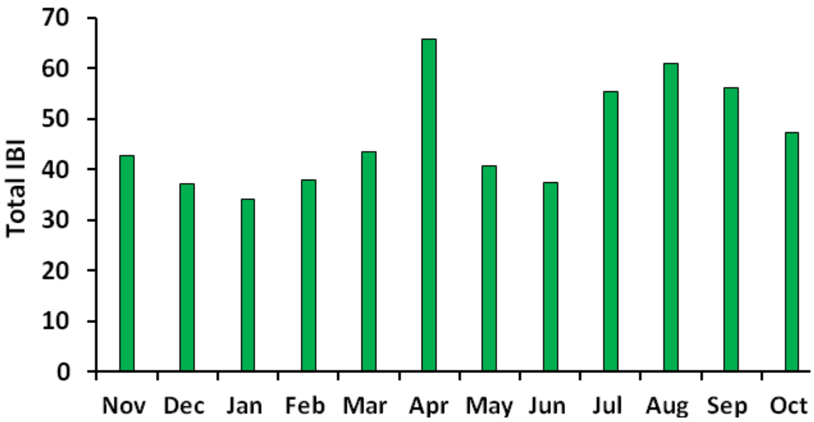

Fig. 7. Monthly variations in the total IBI values in the Garmat Ali River (2015-2016)

The overall F-IBI was significantly positively correlated with water temperature (r= 0.70, p≤ 0.05), and negatively correlated with salinity, transparency and pH (r = –0.51, -0.68 and -0.72, respectively p≤ 0.05).

Similarity dendrogram between the months based on their IBI score is presented in Fig. 8. Four main groups were distinguished. Group I consists of three subgroups, first includes February and January (similarity level, SL= 31%), second includes November and December (SL = 29%) and third includes March (SL = 48%). Group II includes October (SL = 79%). Group III consists of three subgroups, first includes August (SL = 27%), second includes September and July (SL = 26%) and third includes April (SL = 55%). Group IV, includes June and May (SL = 76%).

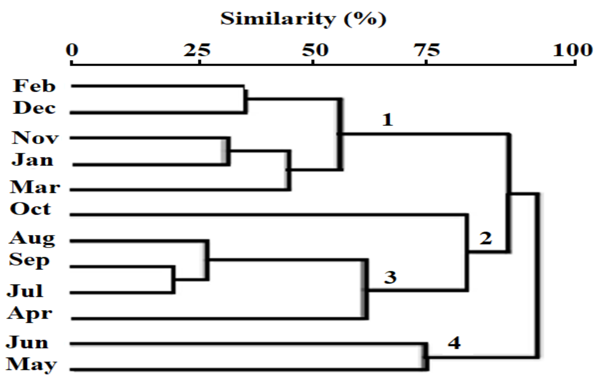

Fig. 8. Similarity dendrogram between the months based on their IBI values in in the Garmat Ali River

4. Discussion

The composition structure of fish assemblage of the river in the present study was clearly changed compared with the previous studies (Younis, *et al.*, 2010 and Mohamed, *et al.*, 2013). The fish fauna of the river comprised of eight native, eight exotic and 18 marine species, constituted 23.5, 23.5 and 52.9% of total number of species, respectively. Younis, *et al.* (2010) found 28 fish species from the river during 2003-2004, 13 species were native species, representing 46.4% of the total number of species, 10 marine species consisted 35.7% and five exotic species formed 17.9%. Moreover, Mohamed, *et al.* (2013) recorded 25 fish species from the river during 2007-2008, 10 (38.5%) of them were native, 10 (38.5%) marine and 6 (23.1%) exotic species.

The study revealed that the water quality index (WQI) of the river was 49.5 which reflect marginal water quality condition. Unfortunately, no previous study existing about WQI on this river, but our results showed apparently changes in some of the environmental parameters, especially higher salinity and the changes in hydrological conditions. Formerly, the range of salinity in the river was 1.33-2.35‰ during 2003-2004 (Younis, *et al*., 2010) and 1.2-3.18‰ during 2007-2008 (Mohamed, *et al.*, 2013), whereas in the present study was 1.5-6.0‰. Also, during the last years, water influx the river was coming primarily from the Shatt Al-Arab River which affected by the tidal current of the Arabian Gulf. 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 in recent years (Al-Tawash, *et al.*, 2013; Brandimarte, *et al.*, 2015; Moyel and Hussain, 2015; Yaseen, *et al*., 2016).

However, the ecological health of the Garmat River using fish integrated biological index (F-IBI) during the present study ranged from impaired (F-IBI= 34.0%) in January to marginally impaired (F-IBI= 65.8%) in April, with overall value was 46.5% evaluated to be impaired. This overall value was lower than that recorded during the period 2007-2008, F-IBI= 53.8% (Mohamed, *et al.*, 2012). There were differences in several individual metrics between the two studies, both positive and negative as show in Table 4. In the present study, some metrics recorded higher values compared with the previous study such as numbers of migratory and exotic species, the proportions of migratory, exotic, omnivores and *P. platipiuna* individuals, and species richness, whereas others were lower values such as the number of native species, the proportions of native, herbivores, carnivores, detrivores, *P. liza* and *C. auratus* individuals. Also, the fish richness index has a general tendency to show high values during the period from March to July which could be attributed largely to the penetration of marine species especially anadromous species, such as *T. ilisha* and *T. whiteheadi*, corresponding with increased in water temperature and decreased in salinity (Mohamed, *et al*., 2017). The assessment of river health using a fish Index of biotic integrity differs from other measures in that it is more holistic; because the fish species are mostly migratory it characterizes the whole waterway, upstream and downstream of the site (Joy and Death 2004).

Table 4. Comparison of F-IBI scores metrics in the Garmat Ali River between 2007-2008 and 2015-2016

IBI metrics	**2007-2008 ***	**2015-2016**
No. of species	26	34
No. of native species	11	8
% of native species	42.3	20.6
% of native individuals	52.3	2.5
No. of exotic species	6	8
% of exotic species	26.9	23.5
% of exotic individuals	34.5	63.3
No. of migratory species	9	18
% of migratory species	34.6	55.9
% of migratory individuals	13.3	34.2
% of *L. abu*	39.3	2.2
% of *C. auratus*	21.2	6.8
% of *P. latipinna*	7.0	53.2
% of herbivores	24.3	4.1
% of carnivores	23	15.6
% of omnivores	7.2	77.8
% of detrivores	45.6	2.4
Species richness	1.3-2.2 (1.6)	1.1-2.3 (1.7)
* Mohamed, *et al.* (2012)		

It is clear from the present study that several cyprinid species disappearance or substantially decreased in abundance of native species, such as *Luciobarbus xanthopetrus*, *Arabibarbus grypus*, *Luciobarbus kersin*, *Mesopotamichthys sharpeyi* and *Carasobarbus luteus* (Richardson, *et al.*, 2005; Mohamed, *et al.*, 2013, 2017). Hughes, *et al.* (2006) mentioned that native species represent the basic building blocks of a fish assemblage, and are a key component of diversity and the exotic species indicate biological pollution and a serious diversion from natural conditions, especially when they constitute a substantial percentage of the assemblage, and including when they are deliberately introduced. The extremely tolerant species are the last to disappear in response do environmental degradation (Costa and Schulz, 2010). Researchers have commonly observed habitat degradation facilitating the underlying mechanisms causing the loss of native fish diversity, the temporal replacement of specialized native fish by exotic fish (Scott and Helfman, 2001; Olden and Poff, 2003; Parks, *et al*., 2014).

5. Conclusions

The study revealed that the ecological condition of the Garmat Ali River is still deteriorating and this requires improving the quality and quantity of water reaching the river from the Tigris and Euphrates rivers.

References

Alaidani, M.A.T. (2014). *The change in the geographic and agricultural properties impacts in the province of Basra* (Unpublished MSc. Thesis). College of Education Sciences, University of Basra.

Al-Mahmood, H.K.H, Hassan, W.F., Alhello, A.Z.A., Hammood, A.I. & Muhson, N.K. (2015). Impact of low discharge and drought of the water quality of the Shatt Al Arab and Al-Basrah Rivers (south of Iraq). *J. Int. Acad. Res. Multidisciplinary*. 3(1), pp. 285-296.

Al-Saboonchi, A.A., Mohamed A.R.M. & Raadi, F.K. (2014). Assessing the Quality of East Hammar Marsh Water using WQI, Basra, Iraq. *Journal of Thi-Qar Science*, 5(1), pp. 24-31.

Al-Saboonchi, A., Mohamed, AR. M., Alobaidy, A.H.M., Abid, H.S. & Maulood, B. K. (2011). On the current and restoration conditions of the southern Iraqi marshes: Application of the CCME WQI on East Hammar marsh. *Journal of Environmental Protection*, 2, pp. 316-322.

Al-Tawash, B., Al-Lafta, H.S. & Merkel, B. (2013). Preliminary Assessment of Shatt Al-Arab Riverine Environment, Basra Governorate, Southern Iraq. *Journal of Natural Science Research,* 3, pp. 120-136.

Al-Tememi, M.K., Hussein, M.A., Khaleefa, U.Q., Ghaleb, H.B., AL-Mayah, A.M. & A.J. Ruhmah, A.J. (2015). The Salts diffusion between East Hammar marsh area and Shatt Al-Arab River Northern Basra City. *Marsh Bulletin,* 10, pp. 36-45.

Belpaire, C., Smolders, R., Auweele, I.V., Ercken, D., Breine, J., Thuyne, G.V. & Ollevier, F. (2000). An Index of Biotic Integrity characterizing fish populations and the ecological quality of Flandrian water bodies**.** *Hydrobiologia,* 434, pp 17-33.

Brandimarte, L., Popescu, I. & Neamah, N.K. (2015). Analysis of fresh-saline water interface at the Shatt Al-Arab estuary. *International Journal of River Basin Management*, 13, pp. 17-25.

Carpenter, K.E., Krupp, F., Jones, D.A. & Zajonz, U. (1997). *FAO species identification field guide for fishery purposes. Living marine resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar and the United Arab Emirates.* FAO, Rome.

CCME (Canadian Council of Minister of the Environment). (2001). *Canadian Water Quality. Guidelines for the Protection of Aquatic life :CCME Water Quality Index 1.0*, Technical Report, Canadian Council of Ministers of the Environment Winnipeg MB, Canada.

Coad, W. B. 2017. *Freshwater Fishes of Iraq*. www.briancoad.com.

Costa, P. & Schulz, U. (2010). The fish community as an indicator of biotic integrity of the streams in the Sinos River basin, Brazil. *Braz. J. Biol.,* 70, pp. 1195-1205.

Durand, J.D., Chen, W.J., Shen, K.N., Fu, C. & Borsa, P. (2012). Genus-level taxonomic changes implied by the mitochondrial phylogeny of grey mullets (Teleostei: Mugilidae). *Comp. Rend. Biol.,* 335, pp. 687–697.

Ganasan,V. & Hughes, R.M. (1998). Application of an index of biological integrity (IBI) to fish assemblages of the rivers Khan and Kshipra (Madhya Pradesh), *India Freshwater Biology*, 40, pp. 367-383.

Hameed, A.H. & Aljorany, Y.S. (2011). Investigation on nutrient behavior along Shatt Al-Arab River River, Basrah, Iraq. *J. Appl. Sci. Res*., 7, pp. 1340-1345.

Hughes, R.M., Whittier, T.R. & Lomnicky, G. (2006). Biological condition index development for the lower Truckee River and Eastern Sierra Nevada Rivers: fish assemblage. *Fisheries,* 301, pp. 15-25.

Joy, M.K. & Death, R.G. (2004). Application of the index of biotic integrity methodology to New Zealand freshwater fish communities. *Environmental Management,* 34(3), pp. 415-428.

Karr, J. R. (1999). Defining and measuring river health. *Freshwater Biology,* 41, pp. 221-234.

Margalef, R. (1968). *Perspectives in ecology*. University of Chicago Press.

Minns, C.K., Cairns, V.W., Randall, R.G. & Moore, J.E. (1994). An index of biotic integrity (IBI) for fish assemblages in the littoral-zone of Great-Lakes areas of concern. *Can. J. Fish. Aquat. Sci*., 51, pp. 1804-1822.

Mohamed, A.R.M. (2014). A fish index of biotic integrity for evaluation of fish assemblage environment in restored Chybaish marsh, Iraq. *Global Journal of Biology, Agriculture and Health Sciences*, 3(1), pp. 32-37.

Mohamed A.R.M. & Hussain, N.A. (2014). Evaluation of fish assemblage environment in Huwazah marsh, Iraq using Integrated Biological Index. *International Journal of Current Research*, 6(4), pp. 6124-6129.

Mohamed, A.R.M., Younis K.H. & Lazem L.F. (2012). Ecological assessment of fish assemblage in the Garmat Ali River Using Integrated Biological Index (IBI). *Basrah J. Agric. Sci.*, 25, pp. 213-227.

Mohamed, A.R.M., Younis, K.H. & Hameed, E.K. (2017). Status of fish assemblage structure in the Garmat Ali River, Iraq. *Journal of Agriculture and Veterinary Science*, 10(2), pp. 17-22.

Mohamed A.R.M. & Abood, A.N. (2017). Dispersal of the exotic fish in the Shatt Al-Arab River, Iraq. *Journal of Agriculture and Veterinary Science*, 10(8), pp. 50 -57.

Mohamed, A.R.M., Hussein S.A. & Lazem, L.F. (2013) Fish assemblage of Garmat Ali River, north of Basrah, Iraq. *Agric. Sci.,* 26, pp. 150-166.

Mohamed, A.R.M., Al-Saboonchi, A.A. & Raadi, F.K. (2015). Ecological assessment of East Hammar marsh in south Iraq using Fish Integrated Biological Index (F-IBI). *Scientific Journal of King Faisal University*, 16(2), pp. 1-11.

Moyel, M.S. & Hussain, N.A. (2015). Water quality assessment of the Shatt al-Arab River, Southern Iraq. *Journal of Coastal Life Medicine*, 3, pp. 459-465.
Olden, J.D. & Poff, N.L. (2003). Toward a mechanistic understanding and prediction of biotic homogenization. *Am. Nat.*, 162, pp. 442-460.
Parks, T.P., Quist, M.C. & Pierce, C.L. (2014). Historical Changes in Fish Assemblage Structure in Midwestern Nonwadeable Rivers. *Am. Midl. Nat*., 171, pp. 27-53.
Partow, H. (2001). *The Mesopotamian Marshlands: Demise of an ecosystem*. Nairobi (Kenya): Division of early warning and assessment, United Nation for Environmental Programs: UNEP publication UNEP/DEWA, 103p.
Richardson, C.J., Reiss, P., Hussain, N.A., Alwash, A.J. & D.J. Pool, D.J. (2005). The restoration potential of the Mesopotamian marshes of Iraq. *Science*, 307, pp. 1307-1311.
Scott, M.C. & Helfman, G.S. (2001). Native invasions, homogenization, and the mismeasure of integrity of fish assemblages. *Fisheries*, 26, pp. 6-15.
Windell, J.T. & Bowen, S.H. (1978). Methods for study of fish diets based on analysis of stomach contents. In T. Bagnel (Ed.), *Methods for the Assessment of Fish Production in Fresh Waters*, pp. 219-226. Oxford: Blackwell Scientific Publications.
Yaseen, B.R., Al-Asaady, K.A., Kazem, A.A. & Chaichan, M.T. (2016). Environmental Impacts of Salt Tide in Shatt Al-Arab-Basra/Iraq. *Journal of Environmental Science, Toxicology and Food Technology*, 10, pp. 35-43.
Younis, K.H., Hussain, N.A. & Mohamed, A.R.M. (2010). Ecological Assessment of Fish Assemblage in Shatt Al-Arab River /Garmat Ali, Basrah Using Integrated Biological Index (IBI). *Journal of the University of Karbala* (special issued, 2010), pp. 22-31.