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Environmental evaluation of the middle part of the Shatt Al-Arab River after saltwater intrusion using the Integrated Biological Index (IBI)

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Abstract
The environment of the Shatt Al-Arab River, Iraq after the substantial salinity intrusion in 2018 was evaluated by applying the Integrated Biological Index (IBI). Fish sampling was conducted at two sites in the middle part of the river in Abu Al-Khaseeb (Station 1) and Sindbad (Station 2) from January 2018 to December 2018. The average values of IBI in the two stations were 55.1 and 49.3, respectively and were evaluated to be impaired (<60). However, the values of IBI in Station 1 during October and December were 61.8 and 62.6, respectively, and evaluated to be marginally impaired (60-80) and 60.3, 64.1 and 63.9 in Station 2 during March, July, and September, respectively. Based on the average value of the Integrated Biological Index (IBI), the environment of the Shatt Al-Arab River after the substantial salinity intrusion in 2018 was evaluated to be impaired and was marginally impaired during some months.

Keywords: Integrated biological index, Shatt al-arab, salinity intrusion, Basrah, Iraq

1. Introduction
The Shatt Al-Arab River is one of the main rivers in Iraq, and it is the main source of water in Al-Basrah Governorate, and it has wide uses, including human consumption, irrigation of crops, commercial and industrial uses, transportation and electric power stations, as well as the main uses of agriculture [1]. The water level in the Shatt Al-Arab is affected by the tidal water coming from the Arabian Gulf and this effect depends on the amount of freshwater discharge from the Tigris and Euphrates rivers and that the salinity in the case of low drainage did not extend more than 5 km north of the city of Al-Faw [2]. Several studies have been conducted on the composition of fish assemblages in the Shatt Al-Arab River [3-13].
Karr and Dudley [14] mentioned that the Fish Index of Biotic Integrity (F-IBI) provides a tool for quantifying changes in ecosystem health as a result of habitat degradation or flow alteration, in addition to chronically poor chemical water quality.
The Fish Integrated Biological Index (F-IBI) was used in Iraq for the first time by [15] to assess the environment of fish populations in the Shatt Al-Arab and Garmat
Ali Rivers, which showed good and consistent results in the use of this index. The Integrated Biological Index was applied using fish by many researchers in assessing the environment of water bodies in different regions of Iraq [16-22].
The current study aims to assess the environmental condition of the middle part of the Shatt Al-Arab River using the Integrated Biological index after the strong saltwater intrusion in 2018.

2. Materials and Methods
The results of Mohamed and Hameed [14] were adopted to assess the environment of the middle part of the Shatt Al-Arab River using the IBI, for the period from January 2018 to December 2018 and two selected stations in the middle part of the Shatt Al-Arab (Fig. 1), namely Abu Al-Khasseb (Station 1) and Sindbad (Station 2). Seventeen metrics for calculating the Integrated Biological Index (IBI) were selected from the following main groups to classify the environment of the middle part of the Shatt Al-Arab, as follows [23-25, 15, 12]

A. Species richness group and includes metrics (number of native species, number of alien Species, number of marine species, and number of resident species).
B. Fish assemblage's composition group includes metrics (percentage of individuals of native Species, percentage of individuals of alien species, percentage of individuals of marine Species, percentage of individuals of the tilapia species, percentage of individuals of *Poecilia latipinna*, percentage of individual of *Planiliza abu*).
C. rophic composition group includes metrics (percentage of individuals of carnivore's species, Percentage of individuals of a herbivores species, percentage of individuals of omnivores Species, percentage of individuals of a detrivores species, and percentage of individuals of a Top carnivores species).
D. A group of diversity indices, including metric (diversity index).
E. Salinity values.

The Integrated Biological index was calculated based on the method described by Minns *et al.* [24] and to give the final evaluation score for the study area, the index values were divided into three groups in a similar way to Ganasan and Hughes [26].

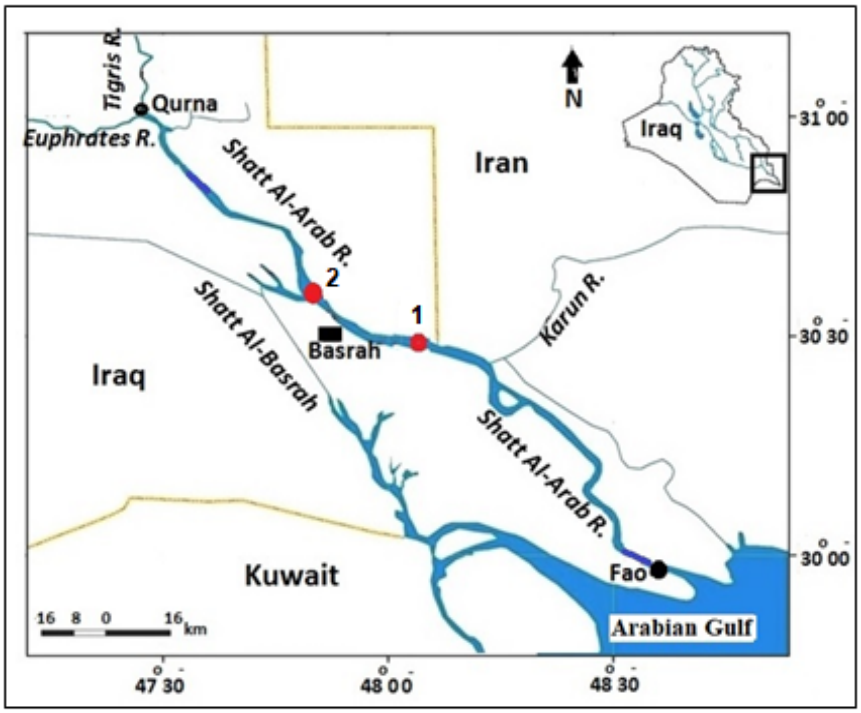

Fig 1: Map of Shatt Al-Arab with locations of study sites

The resident species were determined based on Tyler [27], which appeared in the monthly catch samples from 9 to 12 months. The numerical relative abundance of each fish species was calculated according to Odum [28] as the following:

Relative abundance (%) = (n_i/N) 100

Where
n_i = The number of individuals of the species in the monthly sample.
N = Total number of individuals in the monthly sample.

3. Results

Table (1) shows the distribution of fish according to the metrics used in calculating the IBI to assess the environment of the middle part of the river. Forty-four species belonging to 22 families belonging to the bony fish class were collected in Station 1 and 34 species belonging to 15 families were collected in Station 2. Ten marine species appeared in the first station and did not appear in the second station, which are *Triacanthus biaculeatus, Strongylura, Sola stanalandi, Sola elongta, Otolithes ruber, Cynoglossus kopsii, Platycephalus indicus, Plicofollis dussumieri, Cynoglossus arel, Plicofollis layavdi.*

3.1 Group of species richness

Metric 1: The number of Native species

The number of native species reached eight species in both stations, which is equivalent to 18.2% and 22.9% of the total number of species in both stations, respectively (Table 1). The highest number of native species was recorded in May in both stations, reaching five and six species, equivalent to 21.7% and 27.3% of the number of species caught in this month, respectively, and the lowest (1) in January and October in Station 2, while the disappearance of these species was recorded in February, August, November and December at Station 1 (Figs. 2 and 3).

Metric 2: Number of alien species

This group also included eight species in both stations, which is equivalent to 18.2% and 22.9% of the total number of species in both stations, respectively (Table 1). The highest presence of species in this group six was recorded in January, April, May, June, and eight in June in both

Table 1: Fish species distribution according to IBI metrics in the Shatt Al-Arab River

Native species	*Alburnus mossulensis, Planliza abu, Alburnus marmid, Aspius vorax, Aphanus dispar, Mystus pluseius Carasobarbus luteus, Silurus triostegus*
Alien species	*Poecilia latipinna, Oreochromis aureus, Coptodon zillii, Carassius auratus, Oreochromis niloticus, Hemicultre leucisculus, Cyprinus carpio, Gambusia holbrooki.*
Marine species	*Teunalosa ilisha, Thryssa whiteheadi, Thryssa vitrirostris, Bathygobius fuscus, Hyporhamhus limbatus, Planiliza subviridis, Photopectoralis bindus, Planiliza klunzingeri, Sillago sihama, Boleophthalmus dussumieri, Thryssa dussumeri, Scatophagus argus, Brachirus orientalis, Sillago arabica, Sillago attenuate, Acanthopagrus arabicus, Planiliza caranata, Nematalosa nasus, Triacanthus biaculeatus®, Strongylura strongylura®, Sola stanalandi®, Sola elongta®, Otolithes ruber®, Cynoglossus kopsii®, Platycephalus indicus®, Plicofollis dussumieri®, Cynoglossus arel®, Plicofollis layavdi®.*
Herbivores species	*Carasobarbus luteus, Oreochromis aureus, Coptodon zillii, Oreochromis niloticus, Scatophagus argus.*
Carnivores species	*Alburnus mossulensis, Alburnus marmid, Aphanus dispar, Mystus pluseius, Gambusia holbrooki, Thryssa whiteheadi, Thryssa vitrirostris, Bathygobius fuscus, Hyporhamhus limbatus, Photopectoralis bindus, Sillago sihama, Thryssa dussumeri, Boleophthalmus dussumieri, Thryssa dussumeri, Brachirus orientalis, Sillago arabica, Sillago attenuate, Acanthopagrus arabicus, Triacanthus biaculeatus, Strongylura strongylura, Sola stanalandi, Sola elongta, Otolithes ruber, Cynoglossus kopsii, Platycephalus indicus, Cynoglossus arel.*
Detrivores species	*Planliza abu, Planiliza subviridis, Planiliza klunzingeri, Planiliza caranata.*
Omnivores species	*Poecilia latipinna, Carassius auratus, Hemicultre leucisculus, Cyprinus carpio, Teunalosa ilisha, Nematalosa nasus.*
Top carnivores	*Aspius vorax, Plicofollis layavdi, Plicofollis dussumieri, Silurus triostegus.*
Resident species	*Poecilia latipinna, Teunalosa ilisha, Oreochromis aureus, Thryssa whiteheadi, Coptodon zillii, Thryssa vitrirostris, Carassius auratus, Bathygobius fuscus, Hyporhamhus limbatus, Alburnus mossulensis, Oreochromis niloticus, Planiliza subviridis.*

®: Species appeared in station 1 and were not found in station 2

Stations, respectively, and below four in February, September, and October in the first station and three in August and September in Station 2 (Figs. 2 and 3).

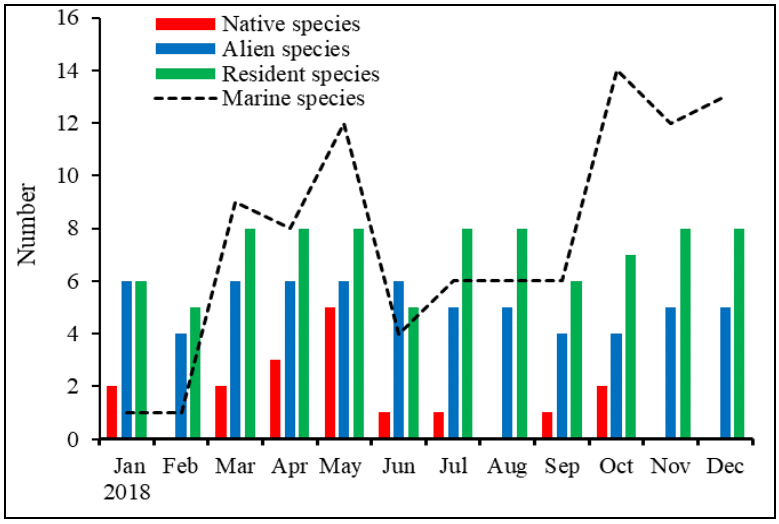

Fig 2: Number of native, alien, marine and resident species in Station 1

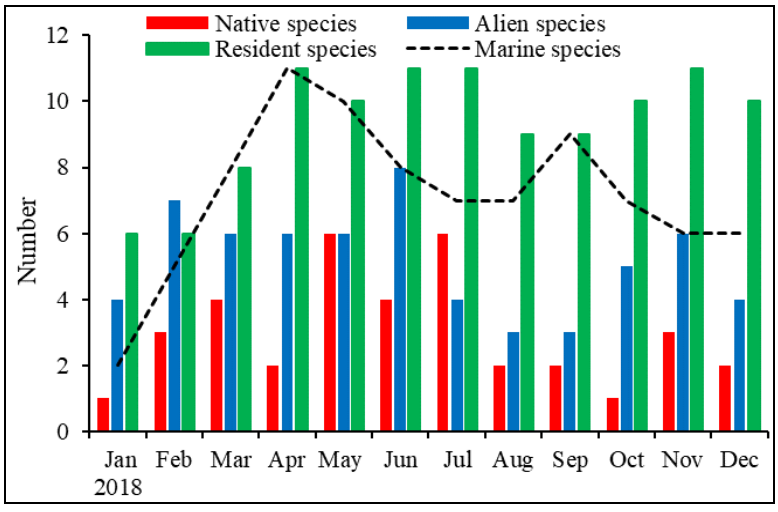

Fig 3: Number of native, alien, marine and resident species in Station 2

Metric 3: Number of marine species
This group included (28) species, including (28) species in Station 1, which is equivalent to 63.6% of the total number of species caught and (18) species in Station 2, equivalent to 52.9%, the highest number of species (14) was recorded in October and below one in January and February in Station 1 and (11) in April and below (2) in January in Station 2 (Figs. 2 and 3).

Metric 4: Number of resident species
This group included (12) species, eight of which appeared in Station 1 and ten species in Station 2. *O. niloticus, P. subviridis* appeared as resident species in the first station and *T. vitriastris, B. fuscus, H. limbatus, A. mossulensis* appeared in Station 2, the highest number of species (8) obtained in March, April, May, July, August, November and December and the lowest (5) in February and June in Station 1 and (11) in April, June, July and November and below (6) in January and February in Station 2 (Figs. 2 and 3).

3.2 Fish assemblage's composition group
Metric 5: Percentage of individuals of native species
The highest percentage of individuals of native species was obtained in Station 2 in July (18.8%), while no high percentage was recorded, but rather its disappearance in several months in Station 1 (Figs. 4 and 5). *A. mossulnsis* and *P. abu* formed the highest percentage of the individuals of the native species, reaching (2.9 and 3.0%) of the total number of fish caught in Station 2, respectively (Fig. 4 and 5).

Metric 6: Percentage of individuals of alien species
The percentages of individuals in this group showed an increase throughout the study period in both stations, the highest percentage of the individuals in this group was obtained in January, reaching (96.7%) and (87.8%) in both stations, respectively, and the lowest percentage is (16.0%) in October in Station 1 and (25.0%) in August and September in Station 2 (Figs. 4 and 5). *O. aureus* species formed the highest percentage in Station 1, amounting to (12.5%) of the total number of fish caught in that station, while *P. latipinna* species formed the highest percentage of alien species in Station 2, reaching (13.8%) of the total number of fish caught.

Metric 7: Percentage of individuals of marine species
The percentage of marine species individuals showed a remarkable increase during the period of the saltwater intrusion, especially in October, reaching (82.8%) in Station 1 and (71.1%) in September at Station 2, and the lowest percentage was obtained in January in both stations, where it reached (1.8%) and (9.5%), respectively (Figs. 4 and 5).
T. whiteheadi formed the highest percentage of marine fish individuals in Station 1, reaching (11.3%) of the total number of fish caught, while *T. illisha* formed the highest percentage of individuals in this group in Station 2, reaching (11.8%) of the total number of fish caught.

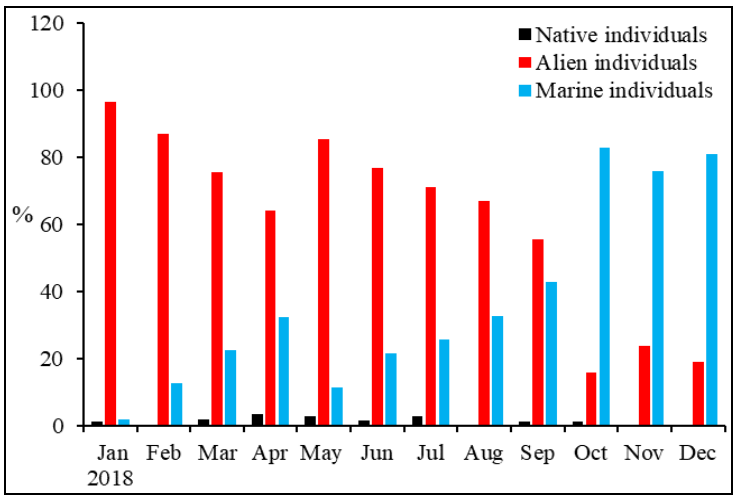

Fig 4: The percentage of individuals of native, alien and marine species in Station 1

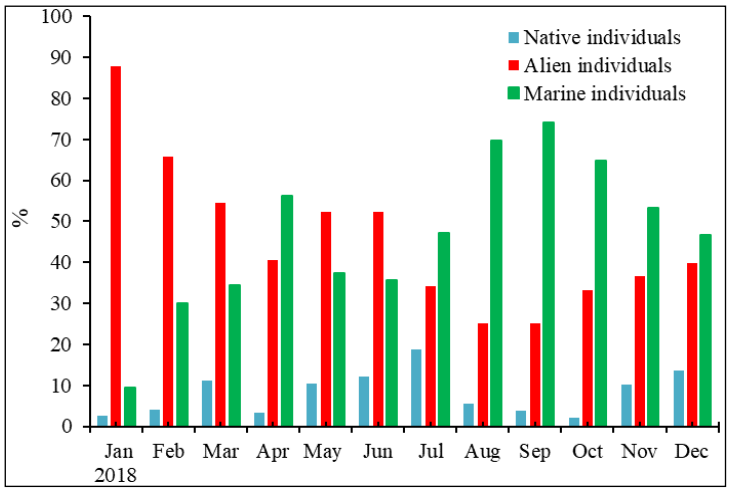

Fig 5: The percentage of individuals of native, alien and marine species in Station 2

Metric 8: Percentage of individuals of the tilapia family
This metric included three species, *C. zillii*, *O. aureus* and *O. nitoticus*, all of which appeared in both stations. The highest percentage of individuals of this family was obtained in May and January, reaching (68.0%) and (67.6%) in the two stations, with the lowest percentage (1.5%) and (11.0%) in June and December in both stations (Figs. 6 and 7). *O. aureus* constituted the highest percentage of individuals of this family in both stations, amounting to (12.5%) and (11.7%) of the total number of fish caught, respectively.

Metric 9: Percentage of individuals of the species *P. latipinna*
Catch 258 and 190 fish of *P. latipinna* in the two stations, which is equivalent to 12.5% and 13.8% of the total number of fish caught, respectively. The individuals of this species were characterized by their continuous monthly appearance throughout the study period, reaching their highest percentage in June (33.8%) in Station 1 and (23.2%) in March in Station 2 and the lowest (0.4%) and (3.3%) in October and August for the two stations, respectively (Figs. 6 and 7).

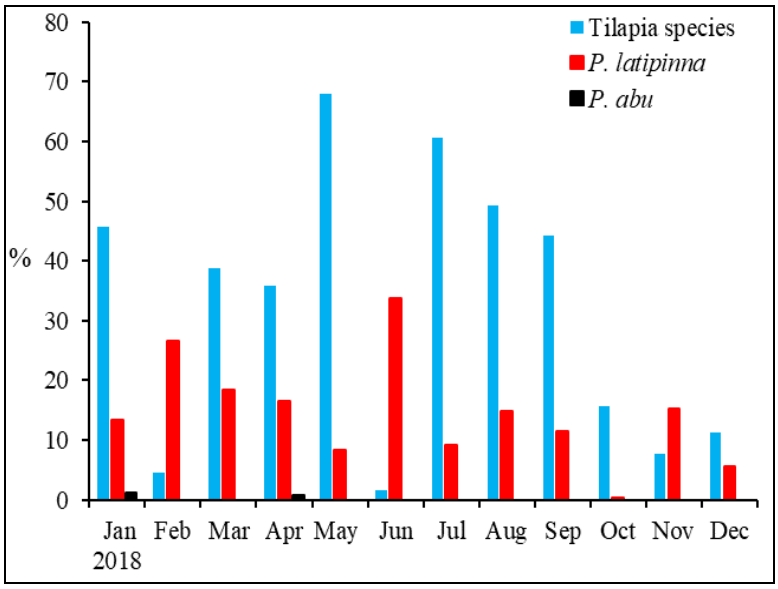

Fig 6: The percentage of individuals of tilapia species, *P. latipinna* and *P. abu* in Station 1

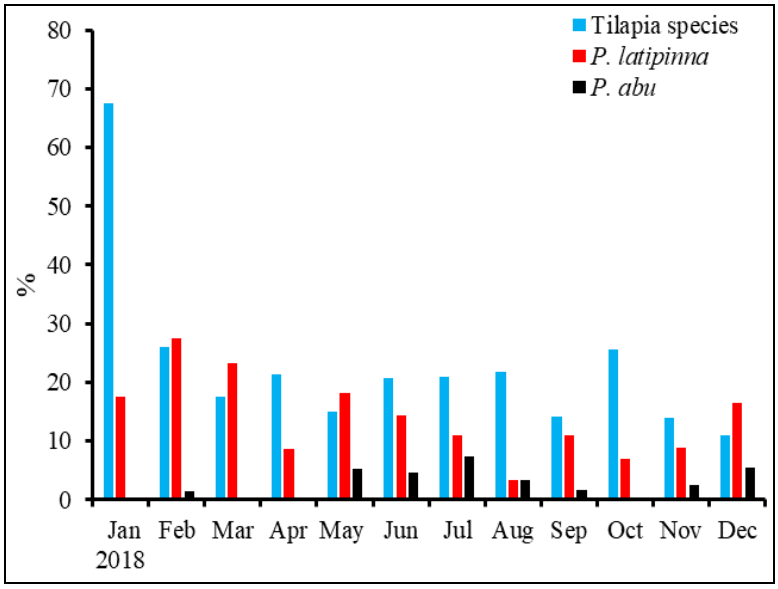

Fig 7: The percentage of individuals of tilapia species, *P. latipinna* and *P. abu* in Station 2

Metric 10: Percentage of individuals of the *P. abu*
The total percentage of *P. abu* individuals for the two stations reached 0.19 and 2.9% respectively and the highest percentage of *P. abu* individuals (0.7%) and (7.3%) was obtained in April and July for both stations, respectively. The disappearance of this species was recorded throughout the study period except in January and April in Station 1 and in January, March, April and October in Station 2 (Figs. 6 and 7).

3.3 Trophic composition group
Metric 11: The percentage of individuals of carnivores' species
This metric included 26 species, 21 out of them were marine and five freshwater species (Table 1). The highest percentage of individuals of carnivores species (78.5%) was obtained in December at Station 1 and 50.8% in August in Station 2 and the lowest value (5.4%) in January in Station 2, while this group was not recorded in February in Station 1 (Figs. 8 and 9). *T. whiteheadi* constituted the highest percentage of species

of carnivores in both stations reaching 11.3 and 9.9% of the total number of fish caught, respectively.

Metric 12: Percentage of individuals of herbivores species
This group included four freshwater species: *C. luteus*, *O. aureus*, *C. zillii* and *O. niloticus*, and one marine species *S. argus*. The highest percentage of this group was obtained in May (68.2%) and January (67.6%) and the lowest (3.1%) in June and (11.0) in December for both stations, respectively (Figs. 8 and 9). *O. aureus* formed the highest rate of individuals in this group in both stations, reaching 12.5 and 11.7% of the total number of fish caught, respectively.

Metric 13: The percentage of individuals of detrivores species: This group included four species included three marine species *P. subviridis*, *P. klunzengeri* and *P. caranata*, and one species of freshwater species *P. abu* (Table, 1). The highest percentage of the individuals obtained in Station 1 (22.8%) during April and 13.0% in August in Station 2 of the total number of the fishing catch while no individual in this group was recorded in February in station 1 and January and March in station 2 (Figs., 8 and 9). *P. subviridis* represent the highest percentage of the species of this group in both stations, and it reached 5.2 and 3.0% of the total number of fish, respectively.

Metric 14: Percentage of individuals of omnivore's species
This metric included six species that included four marine species and two species of freshwater (Table, 1). The highest percentage of the individuals of this group was obtained in February for both stations, reaching 95.4% and 58.9%, respectively. The lowest (1.2%) was in October in Station 1 and (19.6%) in August in Station 2 (Figs. 8 and 9). *C. aratus* reached the highest percentage in this group in Station 1 and reached 12.3% of the total number of fish, while *P. latipinna* was the highest percentage of the species of this group in Station 2 and reached 13.8% of the total number of fish.

Metric 15: Percentage of individuals of top carnivores
This group included four species, including two marine species *P. layavdi*, *P. dussumieri* and two freshwater species, *A. vorax* and *S. triostegus* (Table 1). The percentages of individuals in this group appear to a low percentage throughout the study period in the two stations and disappearance in several months (Figs. 8 and 9). *A. vorax* formed the highest percentage of species in this group in both stations, reaching 0.19 and 0.58% of the total number of fish caught, respectively.

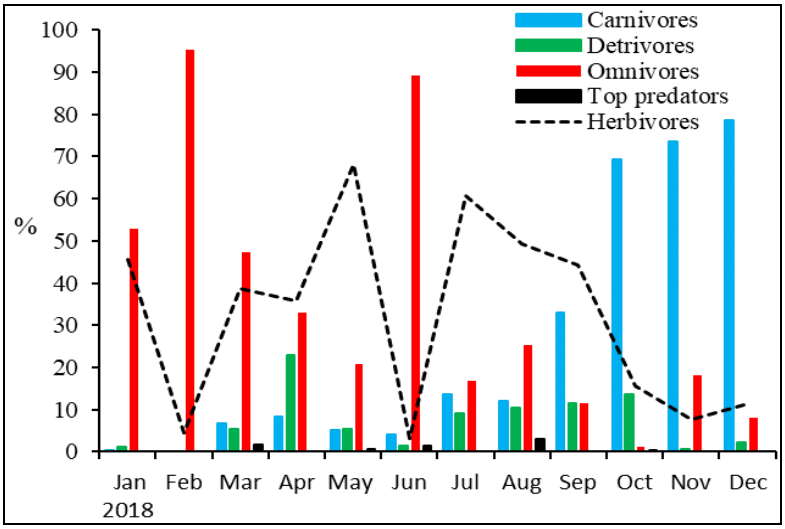

Fig 8: The percentage of individuals of carnivores, detrivores, omnivores, herbivores and top carnivores in Station 1

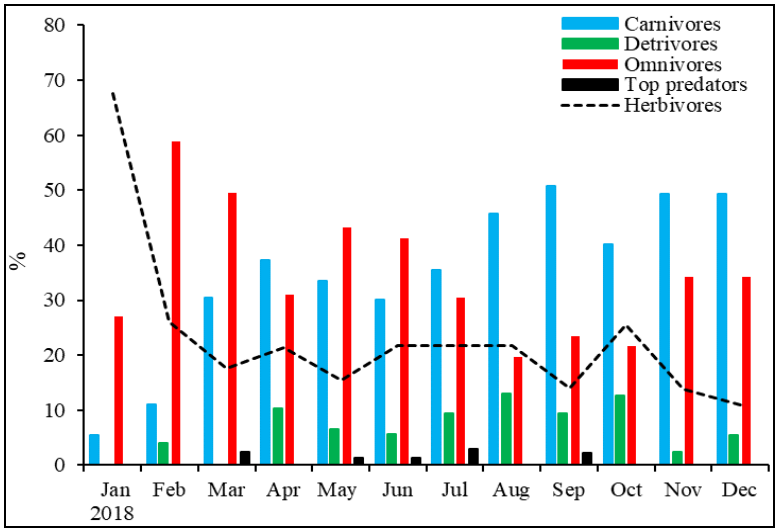

Fig 9: The percentage of individuals of carnivores, detrivores, omnivores, herbivores and top carnivores in Station 2

3.4 A group of diversity indices

Metric 16: Diversity Index (H)

The diversity index (H) values in Station 2 were characterized by high compared to the values obtained in Station 1, where the values of diversity (H) for Station 1 ranged from 0.49 in September to 2.15 in March compared to Station 2, which ranged from 1.51 in January to 2.9 in September (Fig. 10).

3.5 Salinity values

Metric 17: Salinity values

Salinity values fluctuated between both stations, with the lowest values reaching 2.0% in January and the highest in the period from July to October, reaching 14.4, 25.0, 22.5 and 24.3%, respectively in Station 1, while it reached the lowest values in Station 2 were 2.3% in May, and also the highest in the period from July to November, reaching 7.2, 16.2, 14.6, 14.2 and 8.8%, respectively (Fig.10).

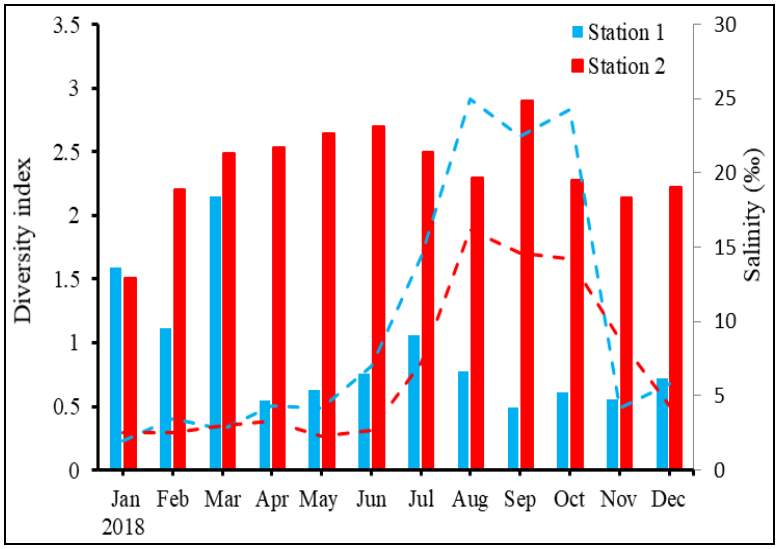

Fig 10: Diversity of fish and salinity in Stations 1 and 2 during the study period.

3.6. Integrated Biological Index (IBI)

The average values of the Integrated Biological index (IBI) for both stations were 55.1 and 49.3, respectively, and they were evaluated to be impaired (<60), except October and December in Station1 were evaluated to be marginally impaired (60-80), where it reached 61.8 and 62.6, respectively, and in March, July, and September in Station2, where the index value reached 60.3, 64.1 and 63.9, respectively. The highest index values (62.6%) and (64.1%) were obtained in December and July, and the lowest values were 34.5 and 40.2 in February for both stations, respectively (Fig. 11).

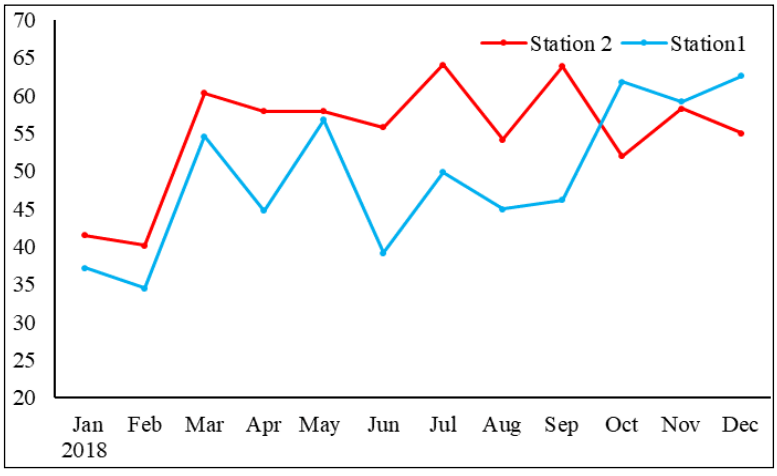

Fig 11: The value of the Integrated Biological Index (IBI) for both stations

4. Discussion

Salt intrusion is defined as the phenomenon of salty marine water advancing toward the upper river, and it is one of the problems in estuarine environments in the world that threatens the preservation of the ecosystem and the optimal use of freshwater [29]. The phenomenon of salt intrusion recurs almost every year in the Shatt Al-Arab River, the water decrease, deterioration of its quality and approaching characteristics of seawater almost invade it every summer, especially during June, July and August [30].

The decrease in water discharge into the Shatt Al-Arab River from the Tigris and Euphrates rivers, and the diversion of the Karun River towards Iranian lands away from the river, led to the intrusion of saline water coming from the Arabian Gulf to the upper Shatt Al-Arab River to reach the northern city of Basrah [31-33].

Several studies referred to the deterioration of the Shatt Al-Arab waters, which they attributed to the decrease in freshwater discharge from the Tigris and Euphrates rivers, and the negative impact of the entry of marine water from the

Arabian Gulf [34-36]. The results of the current study showed an increase in salinity values at both stations, especially in the period from June to October in Station1, reaching 25% in August and from July to November at Station 2, reaching 16.2%. Also in August, this is due to the decrease in water releases from the regulator of Qalaat Saleh, which reached its lowest level (37%) in January [37].

The Integrated Biological Index (IBI) gives a clear indication of the evaluation of water bodies according to specific criteria and is considered one of the important methods that help in managing water resources and protecting them from environmental degradation [38]. The results of the current study showed a decrease in the average values of the IBI in the middle part of the river and for the two selected stations, respectively (55.1 and 49.3), and they were evaluated to be impaired (<60) and a significant decrease in the value of the index during the period of decreasing discharge of water coming to the river and this is due to the changes in the composition of the fish assemblages which was greatly affected by environmental changes as a result of the change in the Shatt Al-Arab discharge and the incursion of salt intrusion, and this was confirmed by Al-Najjar [39], where he pointed out that the climatic changes taking place in the region include rising in the temperature and the progress of the salt intrusion from the Gulf, in addition to an unprecedented record the various pollutants have changed the composition of the fish assemblage in the river.

The decrease in the values of the IBI in the current study reflects the state of environmental disturbance in the middle part of the river, which resulted in a decrease in the number of native species and their disappearance in several months, especially in Station1, and an increase in the number of alien and marine species, and this is the same as what Karr *et al.* [40] noted, where he pointed out that the number of native species normally decreases with the increase in disturbance and that the increase in the number and abundance of alien species may represent one of the forms of disturbances resulting from human influences and that the entry of these species represents a biological disturbance that increases with the deterioration of water quality and the environment [41-43].

The current study indicates a decrease in the percentage of individuals of the native species, especially the *P. abu*, and even its disappearance in ten months in the first station, which is considered one of the native fish and that bears different ranges of environmental conditions after it made up high percentages of the fish population in previous studies, where it formed 58% in the study of Younis *et al.* [15] in the Garmat Ali Rive and 51% in the study of Al-Shamary [16] in the Al-Hammar Marshes, the reason for this may be due to the low rates of water discharges from the Shatt Al-Arab River, as well as the competition between local and alien species. These results seem to support the hypothesis that exotic species have a greater impact when environmental degradation is high and water quality declines [44-46].

Among the other reasons that led to the decline in the index values is the high percentage of alien species in the middle part of the river, reaching its highest levels of 96.7 and 87.8% in January for both stations. Another reason that led to the decline in the index values is the instability of the food pyramid for the region by calculating the percentage of individuals of the carnivores, herbivores, detritivores and omnivores species, and this result was recorded in many studies that included calculating the IBI [20, 47-48, 15].

5. Conclusion

Based on the average value of the Integrated Biological Index (IBI), the environment of the Shatt Al-Arab River after the substantial salinity intrusion in 2018 was evaluated to be impaired and was marginally impaired during some months.

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