Int. J. Aquat. Biol. (2022) 10(2): 169-180
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Impact succession of drought and flood on diversity indices, abundance, and size range of fish assemblage in Al-Shafi Marsh, southern Iraq

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Abstract: This study was conducted in the Al-Shafi Marsh, north of Basrah City to investigate the effects of succession drought and flooding on the abundance and size spectrum of fish assemblage. Three stations were selected and samples were collected on a monthly basis using various fishing gears such as electrofishing, gill nets, and cast nets. The temperature of the water was 12.50-34.53ºC, and the salinity fluctuated from 1.64 PSU in May to 4.03 PSU in October. The pH ranged from 7.38 in September to 8.17 in March. The water depth in the low flat areas ranged from 33 cm in October to 71 cm in May, while the average depth in the seasonal flat areas ranged from zero in June, July, August, September, and October to 34cm in April. A total of 19 fish species were collected, representing 17 genera and 11 families. Eight fish species were native, eight exotics, and two marines. Cyprinidae was the most abundant family, with four species. The most abundant species were the Abu mullet, *Planiliza abu*, Prussian carp, *Carassius gibelio*, and blue tilapia, *Orechromis aureus* (28.42, 20.97, and 14.90%, respectively). The D3 dominance index was 64.29%. The length groups of the most important sixth commercial fish species ranged from 5 cm in *P. abu* to 31 cm in *Leuciscus vorax*. The diversity index ranged between 1.84 and 2.25, the evenness index 0.74 and 0.88, and the richness index between 1.63 and 2.37. The resident species accounted for 94.82% of the total catch. Seasonal species account 2.76% of all samples. The occasional fish species account for 2.42% of total collected fishes. Based on the results, there was insufficient flood pulsation to stimulate native species to reproduce, combined with overfishing, which resulted in a depletion of the species' biomass, and an increase in the abundance of small medium-sized fish species and small invasive species.

Article history:
Received 16 January 2022
Accepted 21 April 2022
Available online 25 April 2022

Keywords:
Drought
Flood
Abundance
Fish assemblage
Exotic

Introduction

The marshes are unique environments characterized by high diversity and productivity; they contain various living organisms, whether plants or animals (Al-Zaidy et al., 2019; Elsey-Quirk et al., 2019; Zou et al., 2021). They serve important functions for humans, including social and economic value, biodiversity resources, suspended matter filtering and sedimentation, pollution capture, and tourist and recreational opportunities (Xu et al., 2019; Zhang et al., 2020; Vasquez et al., 2022). In marsh habitats, bio-geochemical processes benefit the ecological system and species' life cycles by sustaining and organizing them (Hammer, 2020). They also play a vital role in maintaining the balance of hydrological processes by serving as storage areas during the rainy season, flood control, erosion protection, water supply (Moor et al., 2017), and economical source for food production (Abdullah, 2019). Marshes are stable habitats providing enough food, shelter to protect from predators, and a proper environment for breeding wildlife and conserving the ecosystem's health (Balwan and Kour, 2021).

Anthropogenic activities that increase environmental stress can affect the biological productivity of marsh, resulting in changes in

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community composition, i.e. a decline in richness, a decrease in the occurrence of sensitive and native species, and an increase in exotic species (Aziz et al., 2021). Most primary production in aquatic ecosystems is produced by phytoplankton (Andersen et al., 2016). Previous works have shown a rise in the salinity in southern Iraqi marshes due to a reduction in water discharge from the Tigris and Euphrates rivers. These changes have resulted in decreased fish species such as *Arabibarbus grypus*, *Luciobarbus xanthopterus*, *Mesopotamichthys sharpeyi* and *Carasobarbus luteus* (Hintz and Relyea, 2019).

There is no study on the Al-Shafi Marsh, but there are several studies on other marshes in southern Iraq. Mohamed et al. (2012) assessed the ecological and biological aspects of the fish assemblage in the Chybayish Marsh. Abdullah (2019) investigated the fish assemblage and the impact of drowning and drought oscillations on the fish size spectrum in the Al-Chibyaish Marsh in southern Iraq. Al-Thahaibawi et al. (2019) studied the fish assemblage structure in Al-Huwaizah marsh in southern Iraq. The ecological impacts of exotic and marine migratory species on the fish composition assemblage in East Hammer Marsh were discussed by Abdalhsan et al. (2020). Fish body size is frequently used as the primary criterion for determining the physiological characteristics of a fish species and its role in the ecosystem (Heneghan et al., 2019). Therefore, this study aimed to evaluate the fish assemblage in the Al-Shafi Marsh and the impact of succession drought and flooding on fish abundance and size distribution.

Materials and methods

Al-Shafi Marsh is located north of Al-Basrah City and stretches from southern Al-Qurna to about 20 km to the Al-Deer region and nearly 15 km from east to west. The main water source for the marsh is the Al-Shafi River, which receives its water from the Shatt Al-Arab River. It is approximately 7 km long and 30 km wide. To collect the samples, three stations were selected, including Station 1 (30°51'N, 47°25'E), station 2 (30°51'N, 47°29'E), and station 3 (30°47'N, 47°27'E). The collected fishes' total length (cm) and weight (g) were measured after their catch. From January to December 2020, fish samples were collected monthly. Gill-nets (with a length of 30-40 m and mesh size of 19-45 mm), cast nets, and electrofishing (500V, 10A) were used to catch the fish. Fricke et al. (2020) and Froese and Pauly (2022) were used to identify fish species.

The environmental factors were measured at the time of sampling, including water temperature (°C) measured with a mercurial thermometer, salinity (PSU) and pH were measured with a Lovibond-Sensor (Direct 150 Germany). The following formulae were used to study biodiversity indices of the fish assemblage.

Relative abundance % = $(n_i / N) * 100$ (Walag et al., 2016), where n_i = number of individuals of the species and N = Total number of individuals of all species.

Fish diversity $H = -\sum pi \ln pi$ (Huang et al., 2019), where H = diversity index, and P_i = a proportion of species individuals in the sample.

Richness index $D = S-1/\ln N$ (Nyitrai et al., 2012), where D = Richness index, S = number of species and N = Total number of species.

Evenness index $J = H/\ln s$ (Nyitrai et al., 2012), where J = evenness index and H = diversity index S: number of species.

The species were split into length groups to determine the length frequency of each length group versus the number of fish. The occurrence of species was calculated based on Tyler (1949): Common species are found in monthly catch samples in 9 to 12 months; seasonal species appeared in the monthly catch samples in 6 to 8 months, and occasional fishes catch in 1 to 5 months. Response to succession drought and flooding on the size spectrum of fish assemblage, composition patterns, and species life-history strategies are divided into equilibrium, periodic, and opportunistic groups (Winemiller, 2005; Escalera-Vazquez et al., 2017). The dominance index for the abundant three fish species was calculated using the formula of $D3= [\sum_{i=1}^{3} pi.]\ 100$, where Pi = percentage of the abundant to a total number of individuals * 100. All statistical analysis was performed in SPSS (version 20).

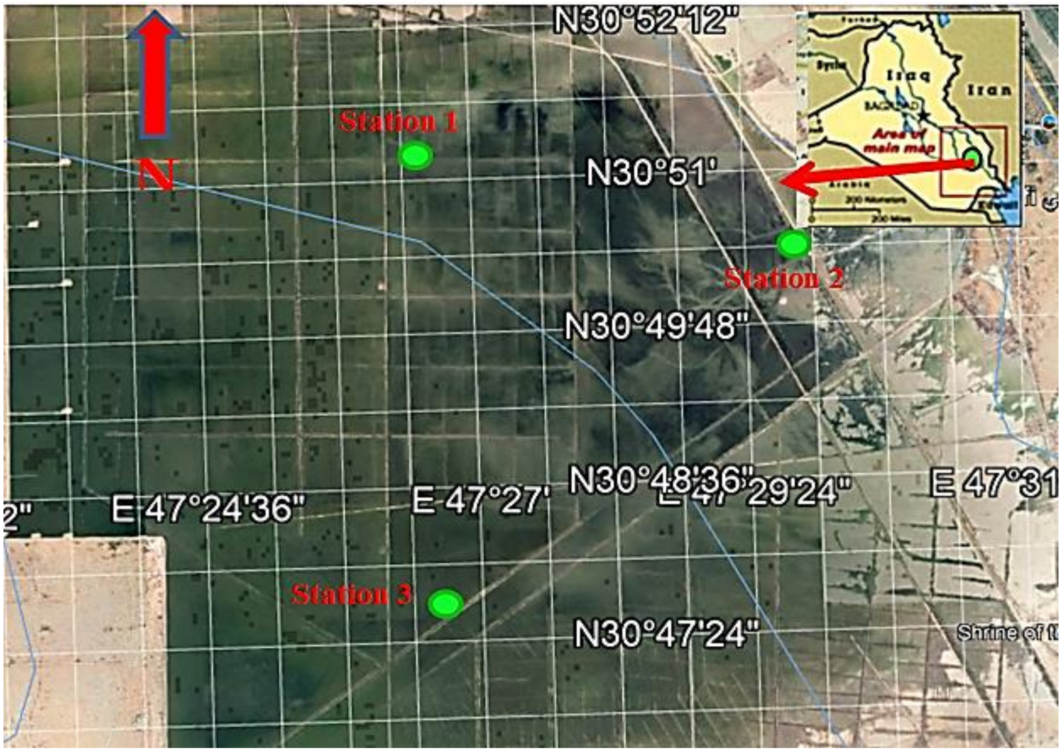


Figure 1. Map of Al-Shafi marsh showed the three selected stations.

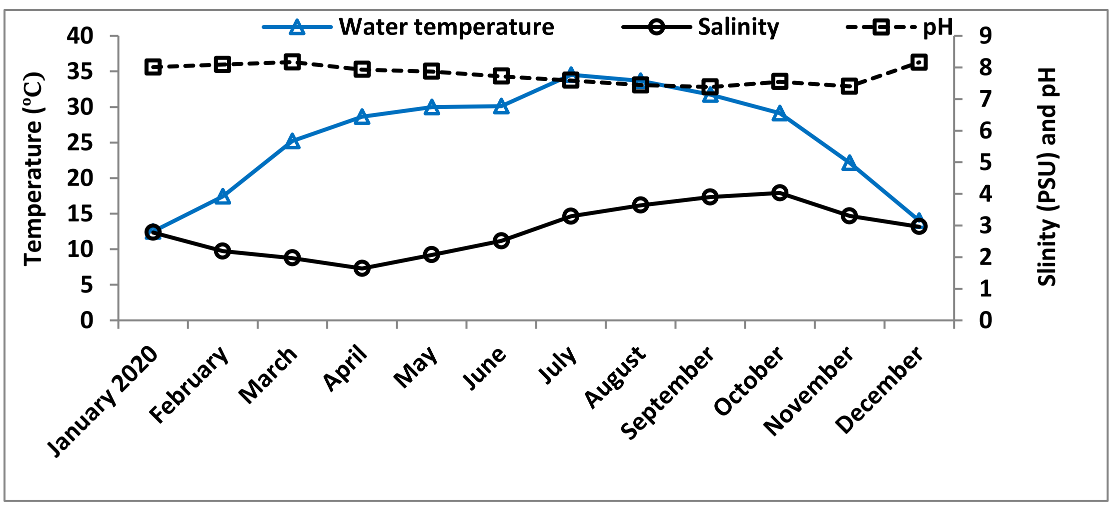


Figure 2. Monthly variations in some ecological factors in Al-Shafi marsh.

Results

Based on the results, the mean water temperature showed high seasonal variations (25.76±7.56°C) (Fig. 2). In January, the lowest water temperature was 12.50°C and rose gradually to the highest (34.53⁰C). It declined slowly to 14.0°C in December. In January, the water salinity was 2.78 PSU and reached to the lowest, i.e. 1.64 PSU, in May. It recorded as 4.03 PSU in October and declined to 2.90 PSU in December. Its mean was 2.86±0.79 PSU during the study period. The pH had slight changes ranging from 7.38 in September to 8.17 in March with a mean value of 7.78±0.30. No significant differences (P>0.05) were found between the three stations in water temperature, pH, and salinity. The relationship between water temperature and salinity was a weak positive (r = 0.243). A significant negative correlation (r = - 0.638) was found between water temperature and pH, whereas a significantly negative correlation (r = - 0.752**) was found between salinity and pH.

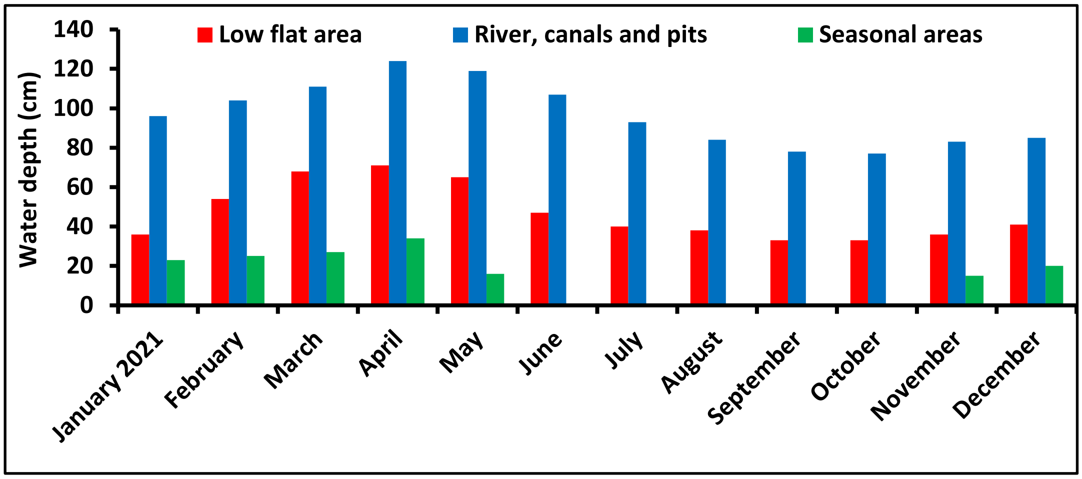


Figure 3. Monthly changes in the water depth in low flat area, river, canals and pits and seasonal area of Al-Shafi marsh.

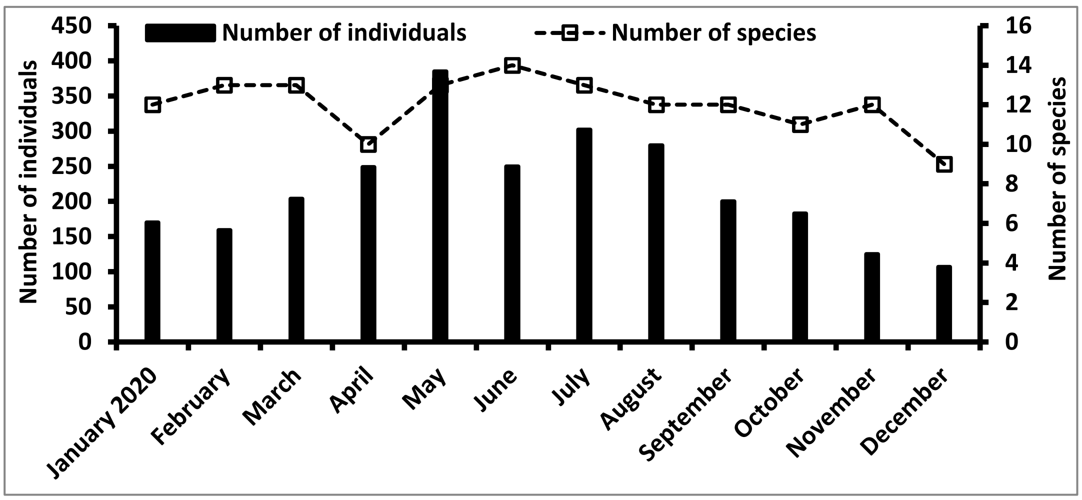


Figure 4. Monthly changes in the number of species and individuals in Al-Shafi marsh.

Marsh hydrology: The hydrology of Al-Shafi Marsh is divided into two categories: permanent inundation areas, including low flat areas, rivers, canals, and small pits, and seasonal inundation areas. The water depth in the low flat areas ranged from 33 cm in October to 71 cm in May, with a mean of 46.83±14.11 cm. The depth in small rivers, canals, and small pits fluctuated from 77 cm in October to 124 cm in April, with a mean of 96.75±16.08 cm. In the seasonal areas, the depth varied from zero in June, July, August, September, and October to 34 cm in April, with a mean of 12.75±11.84 cm. The effect of the tidal events on the marsh was weak (Fig. 3). The water depth had a weak correlation (r = 0.026) (P<0.05) with temperature. A significant negative correlation (r = -0.94**) was found between salinity and water depth of permanent inundation area. A significant positive correlation (r = 0.584*) was detected between pH and water depth of the permanent inundation area.

Species composition: A total of 19 species were collected from Al-Shafi Marsh, belonging to 17 genera and 11 families. Eight fish species were native, nine exotics, and two marines. Cyprinidae was the most abundant family with four species, followed by Cichlidae and Leuciscidae, each with three species, Poeciliidae with two species, and Clupeidae, Engraulidae, Heteropneustidae, Mastacembelidae, Mugilidae, Siluridae, and Xenocyprididae with one species each (Table 1). The total number of species collected from the Al-Shafi Marsh ranged from nine in December to 14 in June. There were no significant (P>0.05) differences in the number of fish species

Table 1. Families and fish species with pointed native, exotic and marine species.

Family	Species	Native	Exotic	Marine
Cyprinidae	*Carassius gibelio*		+	
	Carasobarbus luteus	+		
	Carasobarbus sublimus	+		
	Cyprinus carpio		+	
Xenocyprididae	*Hemiculter leucisculus*		+	
Leuciscidae	*Acanthobrama marmid*	+		
	Alburnus sellal	+		
	Leuciscus vorax	+		
Siluridae	*Silurus triostegus*	+		
Heteropneustidae	*Heteropneustes fossilis*		+	
Mastacembelidae	*Mastacembelus mastacembelus*	+		
Cichlidae	*Coptodon zillii*		+	
	Oreochromis aureus		+	
	Oreochromis niloticus		+	
Poeciliidae	*Gambusia holbrooki*		+	
	Poecilia latipinna			
Mugilidae	*Planiliza abu*			
Engraulidae	*Ttrayssa whiteheadi*			+
Clupeidae	*Tenualosa ilisha*			+

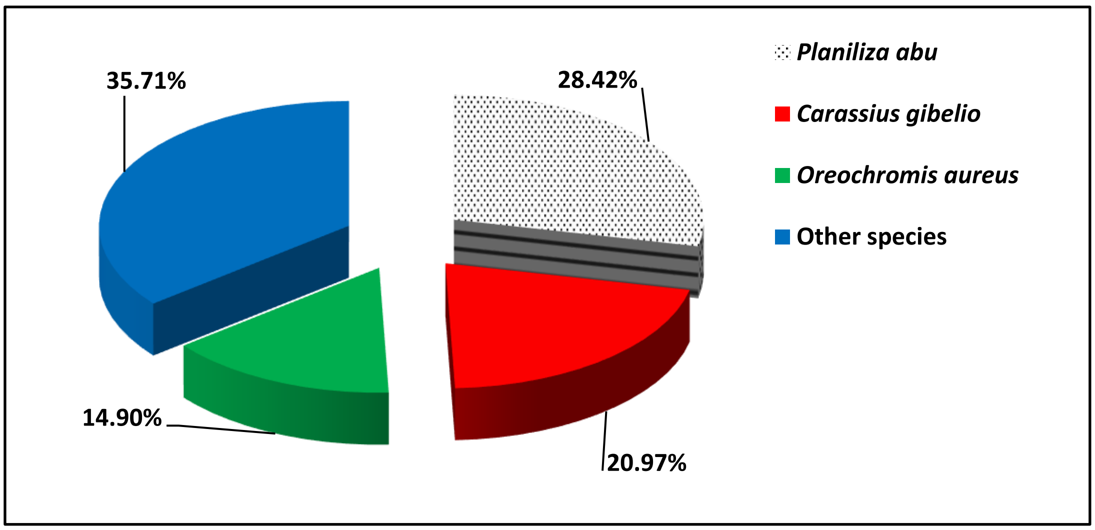


Figure 5. Dominance index (D3) of the most abundance three species in the Al-Shafi marsh.

between the stations (Fig. 4). A total of 2685 fish specimens were collected, with 107 specimens in December and 385 specimens in May (Fig. 3).

Relative abundance: Three dominant species were formed 64.29% of the total number of species (Table 2), including *P. abu* with 28.42% (19.50% in February to 37.65% in January), *C. gibelio* constituting 20.97% (15.88% in January to 28.11% in April) and *O. aureus* formed 14.90% (6.80% in June to 21. 50% in December). Seven species were recorded as less than 1% of the total catch, including *C. sublimus* (0.97%), *A. marmid* (0.78%), *H. leucisculus* (0.78%), *M. mastacembelus* (0.26%), *T. ilisha* (0.19%), *H. fossilis* (0.11%), and *T. whiteheadi* (0.07%). Three families had higher relative abundance at the family level, forming 85.14% of the total catch viz. Cichlidae, Mugilidae, and Cyprinidae (30.76, 28.42, and 25.96%, respectively). The family Leuciscidae recorded

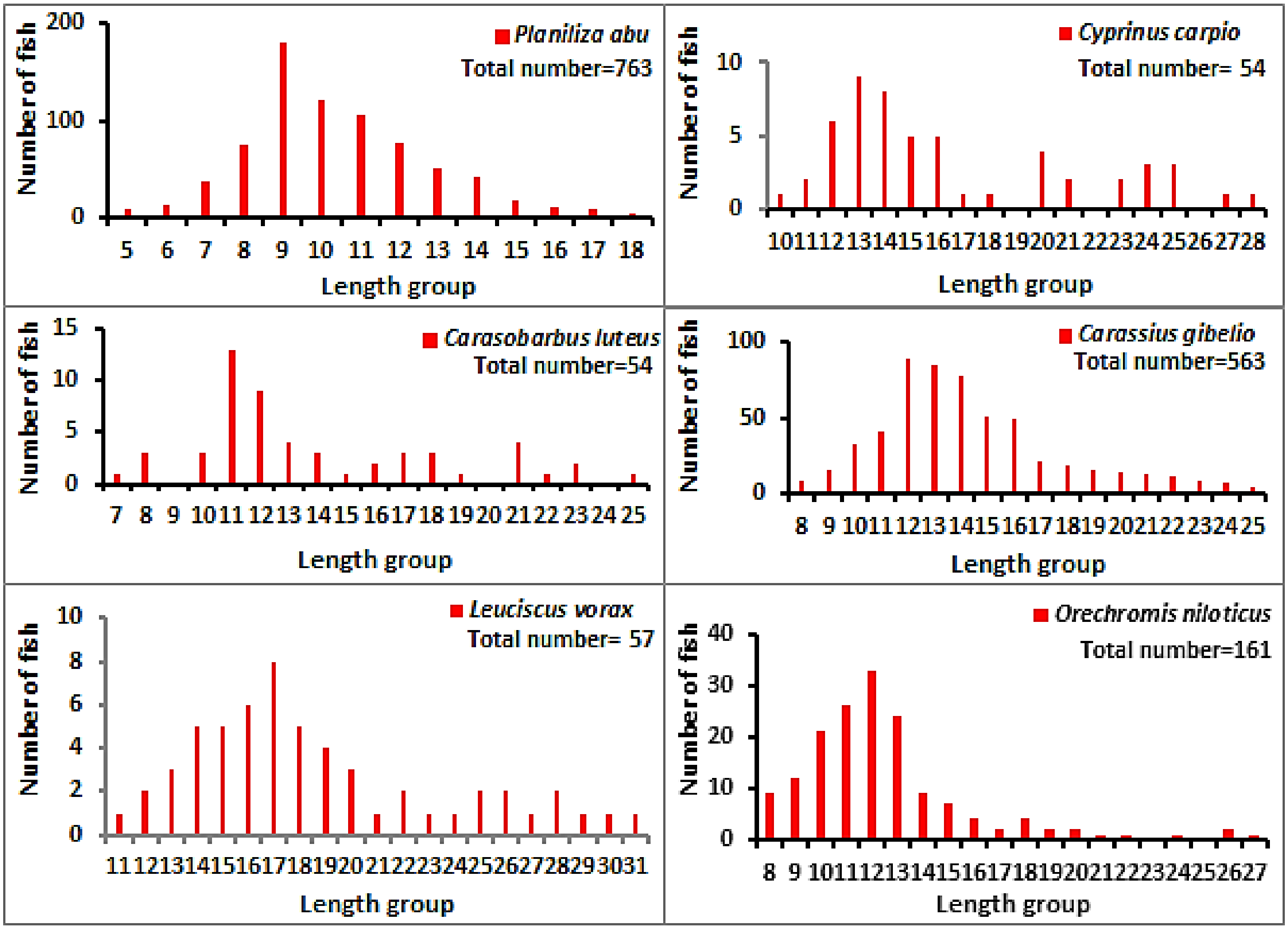


Figure 6. Distribution of fish size-spectrum length groups of the important commercial fish species in Al-Shafi marsh from January to December 2021.

8.49%, Siluridae 2.94%, Poecilidae 2.02%, Xenocyprididae 0.78%, Mastacembelidae 0.26%, Clupeidae 0.19%, Heteropneustidae 0.11%, and Engraulidae 0.07% of the total catch. The dominance index (D3) for the three dominant species (*P. abu, C. gibelio,* and *O. aureus*) was 64.29%, while the remaining species accounted for 35.71% of the total caught (Fig. 5).

Fish size-spectrum: Figure 1 depicts the fish size range versus the number of fish for important commercial fishes (6 species). The total length of *P. abu* ranges 5-18 cm, with 9 cm being the most common size group (n = 181). The size range of *C. carpio* was 10-28 cm, with the dominant length group of 13 cm for nine individuals. The size range of *C. luteus* ranges was 7-25 cm, with the longest length group of 11 cm in 13 fish. The size range of *C. gibelio* was 8-25 cm, with a dominance group of 12 cm in 89 individuals. The monthly samples of 57 fish of *L. vorax* species varied 11-31 cm, with the dominance length group of 17 cm (n = 8). The size range of *O. niloticus* was 8-27 cm, with a dominant length group of 12 cm (n = 33).

Ecological indices: Monthly changes in the fish assemblage's diversity, evenness, and richness indices in Al-Shafi Marsh are shown in Figure 7. With a mean of 1.99, the diversity index (H) ranged from 1.84 in August to 2.25 in February. The evenness index (J) ranged from 0.74 in June to 0.88 in February, with an average value of 0.81. The richness index (D) ranged from 1.63 in April to 2.37 in February, with an average of 2.05.

Occurrence of species: Fish species are divided into three categories based on their frequency in monthly

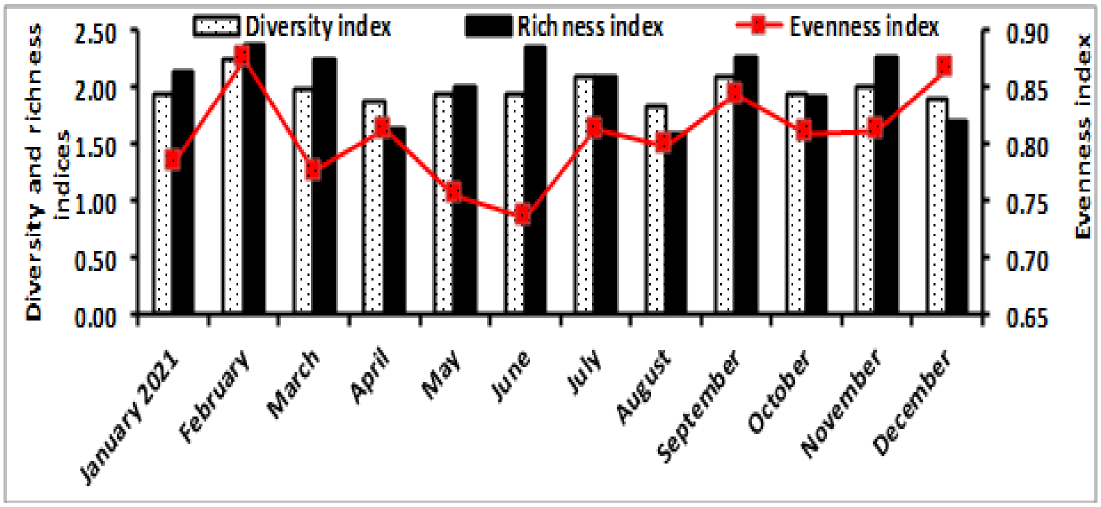


Figure 7. Monthly variations in the ecological indices in the Al-Shafi marsh from January to December 2021.

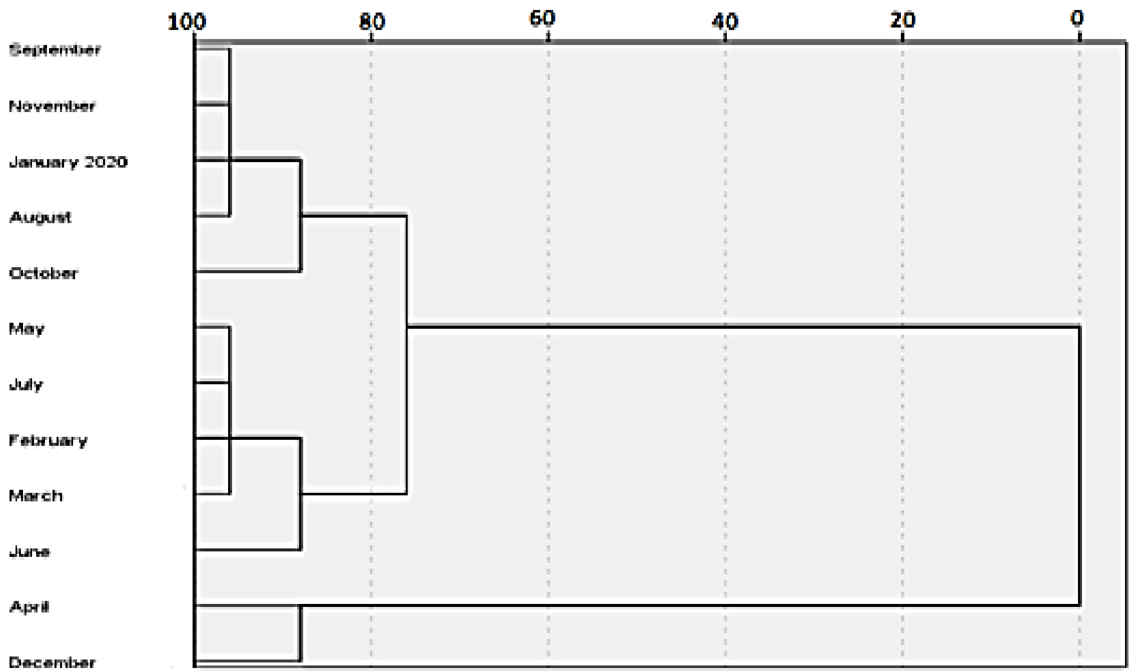


Figure 8. Analysis of cluster for temporal variations of fish species groups in the Al-Shafi marsh north Basrah City.

fishing samples. The resident fish group formed 94.82% of the total catch, including ten fish species, two of them collected in 12 months (*P. abu* and *O. aureus*); four species appeared in 11 months (*A. sellal*, *C. gibelio*, *C. zillii*, and *S. triostegus*); four species were caught in nine months (*C. carpio*, *C. luteus*, *L. vorax*, and *O. niloticus*). The seasonal species formed 2.76% of overall fish, with three species that two of them recorded in seven months (*A. marmid,* and *G. holbrooki*), and one species appeared in six months (*C. sublimus*). The occasional fish species comprise 2.42%, with six species that three of them caught in four months (*H. leucisculus*, *M. mastacembelus*, and *P. latipinna*), whereas one species was collected in three months (*T. ilisha*). The *H. fossilis* species in this group was observed in two months, but the lowest appearance was *T. whiteheadi* which was caught in one month (Table 3).

The cluster's temporal variations revealed two main groups; the first group was divided into two secondary groups. The first secondary group consisted of two groups: September, November, January, and August, but the other groups included October only. The second secondary group was parted into May, July,

Table 2. Monthly variations in the relative abundance of specie in the Al-Shafi marsh.

Species	Jan.	Feb.	Mar.	April	May	Jun.	Jul.	Aug.	Sep.	Octo.	Nov.	Dec.	Total
Planiliza abu	37.65	19.50	31.86	27.31	29.09	27.60	27.48	33.93	26.20	21.31	30.40	26.17	28.42
Carassius gibelio	15.88	20.75	23.04	28.11	19.48	25.60	20.86	20.00	23.25	24.04		19.63	20.97
Orechromis aureus	15.88	15.09	14.22	12.05	19.22	6.80	14.24	14.64	12.55	20.22	16.80	21.50	14.90
Coptodon zillii	6.47	10.06	9.31	12.85	14.03	3.60	10.93	12.14	9.59		15.20	11.21	9.87
Orechromis niloticus	5.29	7.55		6.43	5.97	4.80	6.29		8.86	14.75	15.20		6.00
Alburnus sellal	4.71	5.66	3.92	1.61	2.08	19.20	5.63	7.86		6.56	4.80	7.48	5.59
Silurus triostegus	2.94	3.77	2.94	4.02	3.12	4.80	2.98		3.32	2.19	3.20	1.87	2.94
Leuciscus vorax	3.53	5.03	2.94	2.41	0.78		1.66	4.29	2.21			4.67	2.12
Cyprinus carpio	2.35	3.77	2.94	0.00	1.30		1.32	2.86	4.06	3.28	3.20		2.01
Carasobarbus luteus	2.94	3.77		4.42		1.20	2.65		2.58	3.83	2.40	3.74	2.01
Gambosia holibrooki			1.47	0.80	1.56	0.80		2.14	1.48			3.74	1.01
Poecilia latipinna		1.89	1.96				3.64		3.32				1.01
Carasobarbus sublimus		1.89	2.45		1.04	1.20			1.85	1.64			0.97
Acanthobrama marmid	1.18	1.26	1.96		1.04			1.43	0.74		2.40		0.78
Hemiculter leucisculus					1.30	2.80	1.66				3.20		0.78
Mastacembelus mastacembelus	1.18							0.71		1.09	0.80		0.26
Tenualosa ilisha			0.98			0.40	0.66						0.19
Heteropneustes fossilis						0.40				1.09			0.11
Ttrayssa whiteheadi						0.80							0.07

February, and March, while the second was June. The second mean group consisted of April and December (Fig. 8).

Discussion

The Shatt Al-Arab River is the only source that supplies the marsh; therefore, the salinity concentration of its water depends on this river. The present work documented 19 fish species in the Marsh, however, Abdullah (2019) recorded 15 fish in Al-Chbyish Marsh species, and 19 species were recorded by Al-Thahaibawi et al. (2019) in Al-Huwaizah Marsh.

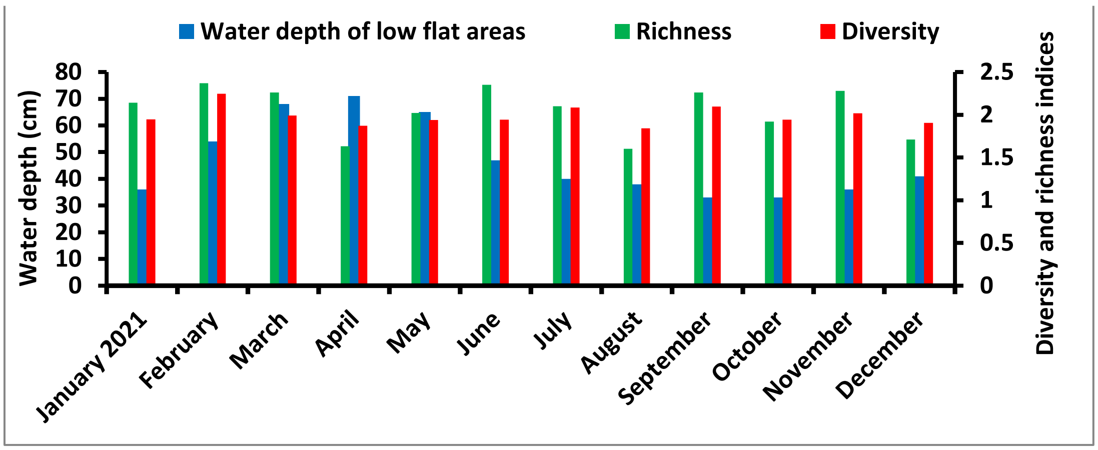
Hydrology is the main driving factor in the wetland's ecosystem dynamics, and the seasonal rainfall raises the water level in the marsh (Grubh and Winemiller, 2018). Temperature is the main controlling factor for water level and conductivity. The rise of water depth increases fish biodiversity, positively affecting food element availability, e.g. allochthonous items associated with plus flooding in the wetlands (Rabuffetti et al., 2017; Yang et al., 2020). In the Al-Shafi Marsh, water depth was the most influential factor limiting fish assemblage. During the flood season, seasonal inundation habitats are critical for spawning, feeding, and nursery grounds for most species, and re-submersion determines fish species' access to breeding, nursery, and foraging habitats (Chea et al., 2020).

Species composition in Al-Shafi Marsh was correlated by hydrological alteration and other factors, e.g. the current seasonal flood pulsation covered the seasonal inundation areas that are important for spawning, and feeding of native cyprinids (Wang et al., 2015), that were the core of the fish community before the introduction of exotic species (Abdullah et al., 2021). A reduction in seasonal flood pulsing and decreasing available spawning grounds are led to insufficient flood periods to stimulate reproduction and a suitable condition for egg incubation and hatching (Yang et al., 2020). In addition, the long-term overfishing caused a decrease in the abundance of fish

Table 3. Fish species occurrence in Al-Shafi marsh from January to December 2020.

Group	Species	Occurrence months	No. of species
Resident fish species	*P. abu*, *O. aureus*	12	2
	A. sellal, *C. gibelio*, *C. zillii*, *S. triostegus*	11	4
	C. carpio, *C. luteus*, *L. vorax*, *O. niloticus*	9	4
Seasonal fish species	*A. marmid*, *G. holbrooki*	7	2
	C. sublimus	6	1
Occasional fish species	*H. leucisculus*, *M. mastacembelus*, *P. latipinna*	4	3
	T. ilisha	3	1
	H. fossilis	2	1
	T. whiteheadi	1	1

Figure 9. Monthly fluctuations of diversity and richness indices values with water depth in the low flat area in Al-Shafi marsh.



species with the absence of some sensitive species (*Mesopotamichthys sharpeyi*) due to changes in flood pulsing and destruction of spawning grounds (Mao et al., 2016; Ding et al., 2016). The flood pulsing during the rainy season is insufficient to stimulate some native species to spawn. Therefore, the native species decrease and competition with exotic species such as tilapia with high abundance results in the decline of important sensitive native species (Abdullah et al., 2021).

Mugilidae was the most abundant native family, represented by Abu mullet, *P. abu*, in Al-Shafi Marsh. This species has adapted to live under extreme temperatures, low oxygen, and feeding on organic detritus and diatoms available at the bottom of the marsh (Mohamed, 2014; Abdullah, 2019). The exotic fish species of Cyprinidae and Cichlidae families (*C. gibelio*, *O. aurea*, *C. zillii*, and *O. niloticus*) were the most abundant and are common in southern Iraq marshes (Al-Thahaibawi et al., 2019; Abdullah et al., 2021). The exotic species are omnivores foraging on low-quality items available in the marsh's habitats, and they have a long active reproductive season reproducing at a young age (Yu et al., 2019).

The fish size range refers to the distribution of biomass in fish populations based on body size classes, and it is a common feature of the fish community (Abdullah, 2019; Vila-Martinez et al., 2019). The results show that the size spectrum of fish appears to be stable due to the fishing, consistent with other findings (Andersen et al., 2016; Rabuffetti et al., 2017; Benoit et al., 2021). The construction of dams at the head of the Tigris and Euphrates river system have reduced the flood pulsation in the southern marshes of Iraq that is crucial to stimulate the reproduction of native species, and this also has been led to an increase in marsh's' salinity, resulting in increasing exotic species and reducing native species (Al-Zaidy and Parisi, 2018; Chea et al., 2020).

The absence of native fish species representing the historical core of fish assemblage and the introduction of invasive species with high abundance can minimize diversity, richness, and evenness indices in the aquatic systems. These indices were within the range of previous studies conducted in inland waters of Iraq e.g. (Ab dalhsan et al., 2020; Abdullah et al., 2021). Several studies showed an increased diversity and richness with rising water depth. However, in the current study, diversity and richness values changed with the water depth in the areas of permanent inundation and relatively became high. This may be attributed to the ease of fishing at low water depth and the efficiency of fishing means (Paller, 2018; Ngor et al., 2018).

Most sensitive species have disappeared and been replaced by native tolerant and invasive species, such as the mullet fish (*P. abu*) and the Prussian carp (*C. gibelio*). Three species of the Cichlidae (*C. zillii*, *O. aureus*, and *O. niloticus*) are occurred because of their tropical origins that are similar to the conditions of the current habitats (Zhang et al., 2020), and these species are dominant in most months of the year (Mohamed and Abood, 2017; Al-Thahaibawi et al., 2019; Abdullah et al., 2021).

Conclusions

The current study revealed that the succession of droughts and flooding and lack of adequate flood pulses during the wet season decline the biomass. This event along with overfishing reduces the fish size spectrum, and increases the abundance of small and medium-sized fish species, resulting in the extinction of commercially important native species and the raising the exotic fishes.

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