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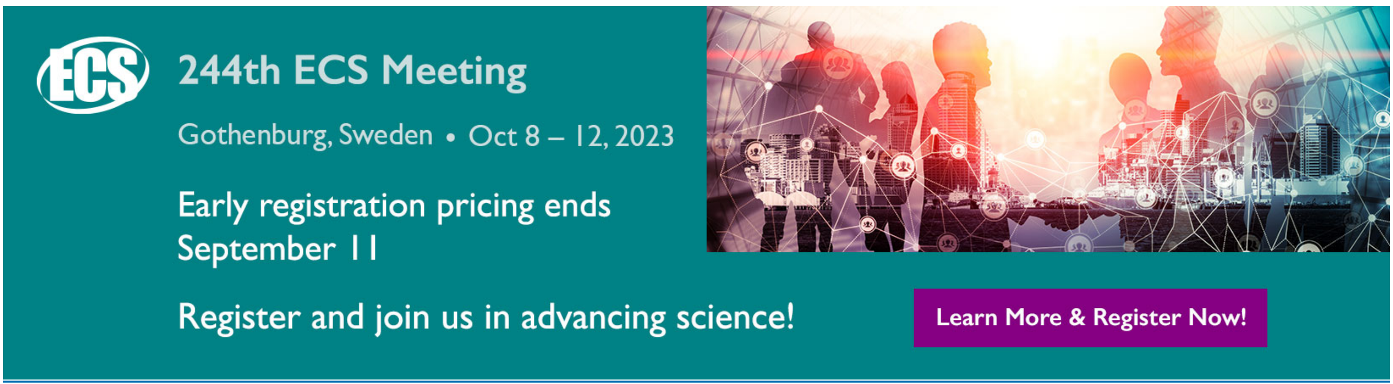

The Impact of Hydrological Changes on Fish Assemblages in the Zachery Marshes of Southern Iraq

Abdul Hussein Jaafer Abdullah

Department of Marine Vertebrate, Marine Science Center, University of Basrah, Basrah, Iraq.

E-mail: abdulhassain.abdulah@uobasrah.edu.iq

Abstract. The present study was implemented in the Zachery Marsh as part of the middle marshes north of Bashar Province from January to December 2022 to investigate the impact of the seasons' oscillation between drought and flooding on fish assemblage abundance, size spectrum, and ecological indices. Three stations were selected to collect samples of fish. The specimens were monthly gathered with different fishing tools, including fixed gillnets, cast nets, and electrofishing. The water temperature ranged from 12.32 to 34.03 ^{0}C, the salinity varied from 1.75 PSU to 2.89 PSU, and the pH fluctuated between 7.47 and 8.43. The rate of change in water depth in the low flat regions fluctuated from 27 cm in September to 76 cm in April. The mean water depth in rivers, small pits, and canals varied from 45 cm in October to the highest, 121 cm in March. In the seasonal regions, the average depth ranged from zero in July, August, September, and October to 40 cm in April. The current study documented 18 fish species belonging to 16 genera and 9 families from Zachery Marsh, all of them affiliated with the Osteichthyes class. Cyprinidae was the most abundant family, including six species. The species *Planiliza abu*, the most abundant species, formed 28.44%, *Carassius gibelio* constituted 20.27%, and *Orechromis aureus* represented 18.52%. The dominance index (D3) of the three dominant species was 67.23%. The size spectrum of the most commercial species was determined. The diversity index value ranged from 1.64 in August to 2.08 in June, the evenness index varied between 0.69 in May and 0.91 in December, and the richness index values fluctuated from 1.47 in August to 2.28 in June. Resident species represented 88.02%, seasonal species formed 6.08%, and the occasional fish species counted for 5.90%. The present study concludes that the fluctuation between drought and flooding has a critical role in the composition of fish assemblages, particularly in seasonal marshes that are subjected to extreme conditions. The fish evolve several reproductive strategies in these difficult conditions in order to survive and continue.

Keywords. Drought, Flood, Zachery Marsh, Size-spectrum.

1. Introduction

The marshes are a one-of-a-kind ecosystem that is unparalleled worldwide, with distinct characteristics that make it diverse and highly productive [1]. The marshes in Iraq can be defined as wetlands because they serve multiple functions identical to those of wetlands that have an impact on neighboring habitats. Al-Zaidy et al. [2] classified marshes as a central location for biological processes that occur within their environments, despite the fact that marshes' functions and characteristics differ from one marsh to the next and that no marsh habitat can provide all services

because operations cannot be performed ideally in the same conditions at every marsh location. The location of the marsh and its extent are what determine the nature of the jobs it performs, and the economic value of the marshes is estimated by the diversity of habitat functions and magnitude of the services they provide to the adjacent populations [3, 4]. Junk et al. [5] reported that the diversity and richness of marshes in fauna and flora, as well as the vast area occupied, cause the major and minor functions to be more important. The most important job that marshes can perform is converting solar light to primary production for use as animal food; raw materials are used in industry; they account for significant economic fisheries; and they are regarded as a cultural legacy for people in neighboring areas [2,6]. Marshes serve a regulatory function for ecosystems represented by biosphere processes and biogeochemical cycles. Marshes function as flood control and water supply, as well as water storage and corrosion reduction to keep soil from running off.
The biological operations of these plants, such as primary production (vegetation), are decaying to produce organic matter, which is essential for the energy cycle [7,8]. Wetlands, on the other hand, are used as a natural filter to improve water quality by removing suspended materials. These habitats, in which animals and plants live, are also used to provide predator protection for other organisms, food, water, breeding areas, and stations for wild birds [9]. The marshes are biologically diverse. They are one of the most notable ecosystems on the planet, with numerous fish species, birds, invertebrates, and a diverse vegetative cover [10].
Many studies have been conducted on the marshes after immersion in 2003 dealt with the assessment nature of fish assemblage [1,9,11,12].
The current study aimed to evaluate fish populations after successive droughts and flooding and their impact on fish composition, abundance, and size spectrum.

2. Materials and Methods

Zachery Marsh is located within the Central Marshlands, north of Basrah Governorate, in southern Iraq. The marsh stretches about 15 kilometers north of the Al-Huwayr district to the border of Missan province. The marsh received water from the Al-Eiz River in the east and the Euphrates River in the south and west. Zachery Marsh includes more than 12 villages. In order to collect the samples, three stations were chosen. Station 1: N 31 14' 63"; E 47 07' 58", station 2: N 31º 07' 41"; E 47 10' 47", station 3: N 31 00' 34"; E 47º 10' 31". The study area's stations were determined using GPS manufactured by the Garmin Company Taiwan (Figure 1). The total length (cm) and weight (g) of the fish were measured in the laboratory. The study was conducted from January to December 2020, fish samples were monthly collected from the current area. Several fishing tools were used to collect samples, such as fixed gill nets (30 to 40 m) in length (19 to 45 mm mesh size), cast nets, and electrofishing by generator engine, all of which were used to catch the fish (500 V, 10 A). Fish classification following [13], and [14] were used to update the rest of the scientific names. The environmental factors were measured concurrently with the sampling process; water temperature (ºC) was measured with a mercurial thermometer, salinity (PSU) was measured with a Lovibond-Sensor Direct 150 Germany-manufactured instrument, and pH was measured with a Lovibond-Sensor Direct 150 Germany-manufactured instrument. The following methods were used to examine the fish assemblage:

$$\text{Relative abundance } \% = (ni / N) * 100$$

due to [15] ni: represented number of individuals of the species N: Total number of individuals of all species.

$$\text{Fish diversity } H = -\sum pi \ln pi$$

following [16] H: diversity index Pi: a proportion of species individuals in the sample.

$$\text{Richness index } D = S\text{-}1/\ln N$$

following [17] D= Richness index S= number of species N: Total number of species.

$$\text{Evenness index } J = H/\ln s$$

following [17] J: evenness index H: diversity index, S: number of species.
The commercial fish species are split into length groups to determine the length frequency of each length group versus the number of fish, and this is done as diagrams. Occurrence of species due to [18] as the following:
Common species that were found in monthly catch samples from 9 to 12 months. Seasonal species appeared in the monthly catch samples from 6 to 8 months. Occasional fish species catch from one to 5 months. Response to succession drought and flooding on size spectrum of fish assemblage in Zachery marsh the assemblage composition patterns, species life-history strategies are identified into three groups: equilibrium, periodic, and opportunistic according to [19, 20]. The dominance index for the most abundant three fish species was

$$D_3=[\sum (i=1)^3 pi.]\ 100$$

Pi=Number percentage of most abundant three species to a total number of individuals * 100. Statistical analysis for correlation relationships was done with SPSS version 20.

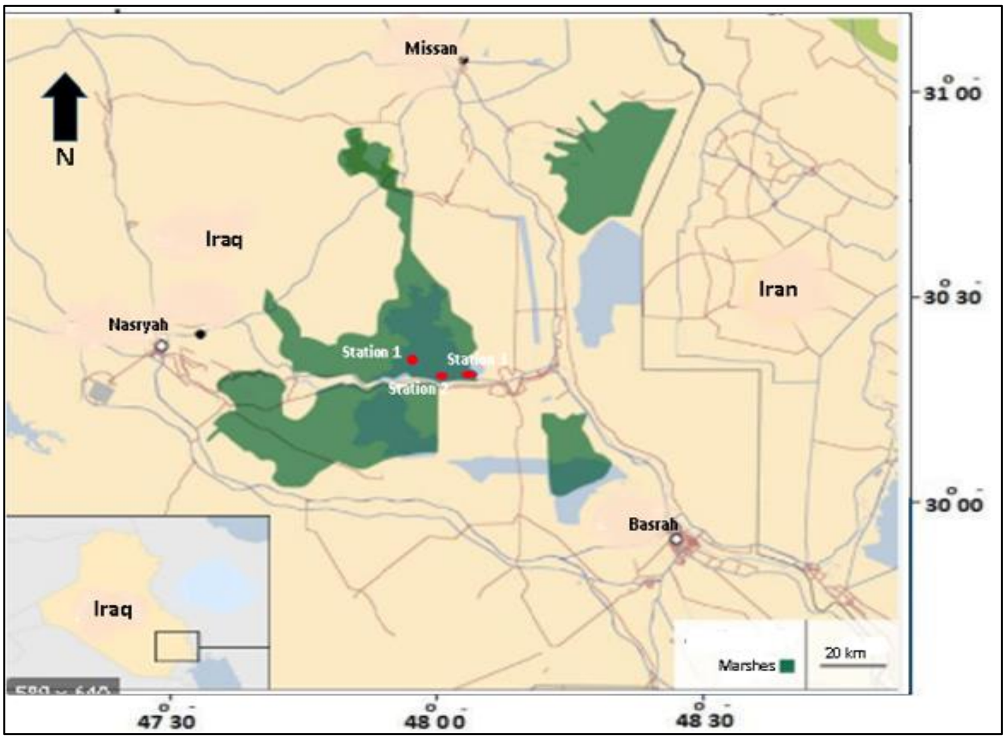

Figure 1. Map of studying area.

3. Results

3.1. Ecological Variables

There are significant variations in the rates of change in water temperature among the year's months (Figure 2). The minimum means were recorded at 12.32 °C in January, then gradually rose to a maximum of 34.03 °C in August before gradually declining to 13.82 °C in December; the mean SD values were 25.48 + 7.43. Water salinity concentrations showed clear changes at the time of sample collection. It was noticed at 1.75 PSU in January, then rose to 2.89 PSU in August. After that, it showed depression to record 1.88 PSU in April, and the mean and ±SD were 2.42 ± 0.55. The pH concentrations showed slight differences in the cold months compared to the hot months to label 7.47 in September, with a maximum value of 8.43 in February, and a mean and SD of 7.77± 0.28. The results showed a weak correlation ($r = 0.15$) between water temperature and the number of species. A weak negative correlation ($r = -0.255$) was detected between salinity and the number of species. A weak negative correlation ($r = 0.114$) was discovered between pH and the number of species. The

ANOVA analysis showed no significant differences (P > 0.05) in the values of water temperature, salinity, and pH among the three stations.

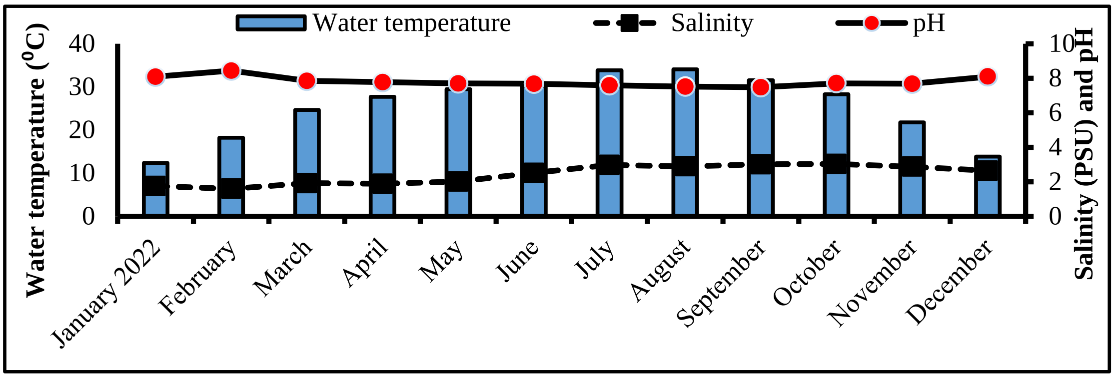

Figure 2. Monthly changes in some ecological factors in Zachery marsh.

3.2. Hydrology of the Marsh

Zachery Marsh hydrology was divided into two parts: permanent inundation regions (low flat regions, rivers, small pits, and canals), and seasonal inundation regions. The average water depth in low flat areas ranged from 27 cm in September to 76 cm in April, with average and standard deviation values of 45.42 cm + 16.62. The mean depth in rivers, small pits, and canals varied from 45 cm in October to the highest 121 cm in March, the mean ± SD values were 85.42±27.70. In the seasonal regions, the average depth ranged from zero in July, August, September, and October to 40 cm in April, and the mean ± SD values were 17.75cm ± 15.51 (Figure 3).

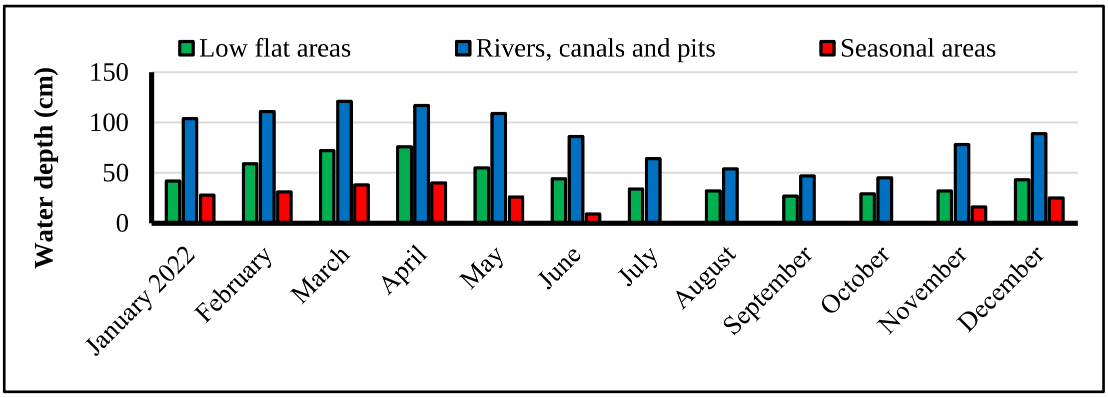

Figure 3. Monthly variations in the water depth in low flat areas, rivers, small pits, canals, and the seasonal region of Zachery Marsh.

3.3. Fish Species Composition

The current study documented 18 fish species belonging to 16 genera and 9 families from Zachery Marsh, all of them affiliated with the Osteichthyes class. Cyprinidae was the most abundant family, with six species. Cichlidae and Leuciscidae have three species each. The remaining six families contain one species each: Heteropneustidae, Mastacembelidae, Mugilidae, Poeciliidae, Siluridae, and Xenocyprididae (Table 1).

3.4. Relative Abundance

In the Zachery marsh, four fish species were dominant the fish assemblage comprises 77.53% of the total number of species in the current marsh (Table 2). The species that recorded the highest percentage of numerical relative abundance was *Planiliza abu*, which formed 28.44% of the overall species and varied from 19.60% in February to 39.83% in May. The species that occupied the second rank was *Carassius gibelio*, which constituted 20.27% of the total catch of species, ranging from 7.54% in February to 32.20% in May. The species *Orechromis aureus*, representing 18.52% of the overall species in the study area, fluctuated between 2.12 in May and 30.00% in August. However, *Coptodon zillii* comprise 10.30% of the total number of species, differing from 3.05% in November to 19.60% in February. Generally, eight species were documented in less than 1% of the total catch: *Carasobarbus sublimus* (0.95%), *Hemiculter leucisculus* (0.61%), *Gambosia holibrooki* (0.57%), *Mesopotamichthys sharpeyi* (0.57%), *Acanthobrama marmid* (0.46%), *Mastacembelus mastacembelus* (0.34%), *Heteropneustes fossilis* (0.15%), and *Cyprinon kais* (0.15%).

Three families, Cichlidae, Mugilidae, and Cyprinidae, forming 88.17% of the total caught, preside over the relative abundance, comprising 32.62%, 28.44%, and 27.11%, respectively, at the family level, forming 88.17% of the overall catch in the current marsh. Broadly the rest families were recorded 11.83% of the total number of species including: Leuciscidae formed 7.87%, Sulridae 2.28%, Xenocyprididae 0.61%, Poecilidae 0.57%, Mastacembelidae 0.34%, and Heteropneustidae 0.15% (Table 2). The dominance index (D3) of the three dominant species (*P. abu*, *C. gibelio*, and *O. aureus*) was 67.23% of the total number of species, while the remaining species accounted for 32.77% of the entire capture in Zachry Marsh (Figure 4).

Table 1. Families, fish species, native, and exotic species in the Zachery marsh.

Family	Species	Native	Exotic
Cyprinidae	*Carassius gibelio*		+
	Carasobarbus luteus	+	
	Carasobarbus sublimus	+	
	Cyprinus carpio		+
	Mesopotamichthys sharpeyi	+	
	Cyprinion kais	+	
Xenocyprididae	*Hemiculter leucisculus*		+
Leuciscidae	*Acanthobrama marmid*	+	
	Alburnus mossulensis	+	
	Leuciscus vorax	+	
Siluridae	*Silurus triostegus*	+	
Heteropneustidae	*Heteropneustes fossilis*		+
Mastacembelidae	*Mastacembelus mastacembelus*	+	
Cichlidae	*Oreochromis aureus*		+
	Oreochromis niloticus		+
	Coptodon zillii		+
Poeciliidae	*Gambusia holbrooki*		+
Mugilidae	*Planiliza abu*		

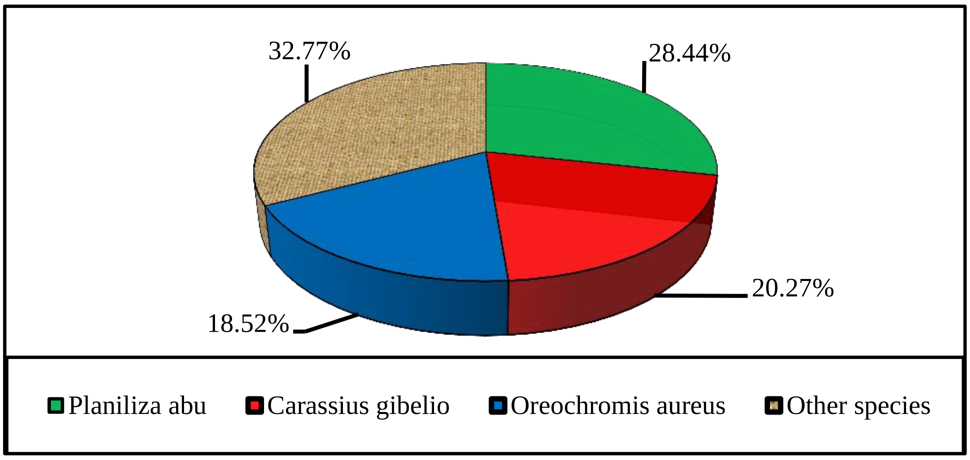

Figure 4. Dominance index (D3) of the three most abundant species in the Zachery.

3.5. MarshNumber of Species and Individuals

The range of species numbers that catches from Zachery Marsh fluctuated between nine species in December to 14 species in June. The data analysis revealed no significant differences ($p > 0.05$) in the number of species between the three stations. As a consequence, 2630 fish were caught from the present marsh during the study period, ranging from 133 specimens in December to 297 specimens in June (Figure 5). The correlations between the number of individuals and temperature, salinity, and pH ($r = 0.269$, $r = -0.34$, and $r = -0.24$), respectively. The examination of the data revealed no significant differences ($p > 0.05$) in the number of individuals of each species across the currently selected stations.

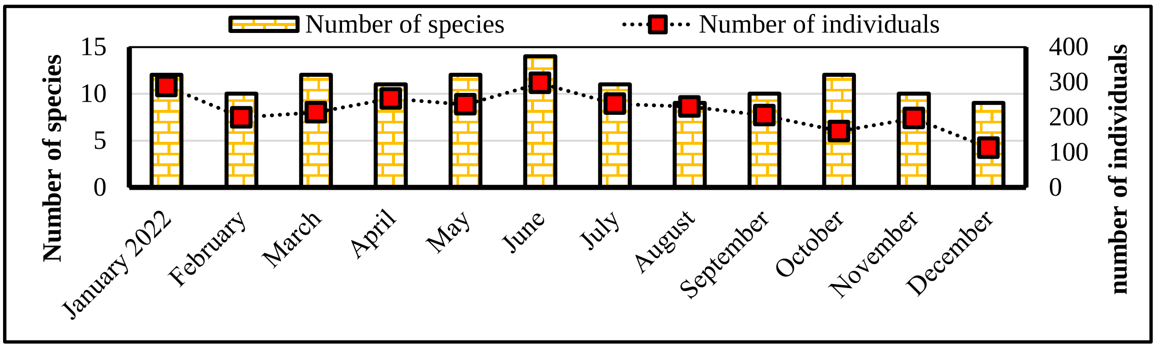

Figure 5. Monthly changes in the number of species and individuals in the Zachery Marsh.

3.6. Species Occurrence

According to their occurrence, fish species are divided into three divisions: Resident species occur from (9 to 12 months) and represented 88.02% of the total number of species. They included eight species: *P. abu*, *C. gibelio*, and *O. aureus*, caught in 12 months. The species *A. mossulensis* and *C. luteus* appeared in 11 months. Three species, *C. zillii*, *L. vorax*, and *C. carpio*, were sampled in ten months. The seasonal species (6 to 8 months) formed 6.08% of the total caught in Zachery Marsh and consisted of two species: *O. niloticus* and *S. triostegus*. The occasional fish species (1 to 5 months) counted for 5.90% of the total number of fish, including eight species: *C. sublimus* and *H. leucisculus* observed in five months; *M. sharpeyi* and *A. marmid* catches in four months; *G. holibrooki* and *M. mastacembelus* sampled in three months; and *H. fossilis* and *Cyprinon kais* captured in two months (Table 3).

Table 2. Monthly changes in the relative abundance of fish species in the Zachery Marsh.

Family	Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Octo.	Nov.	Dec.	Total
Mugilidae	*Planiliza abu*	29.86	19.60	33.18	24.90	39.83	26.60	29.83	31.74	22.44	23.75	30.96	23.89	28.44
Cyprinidae	*Carassius gibelio*	15.97	7.54	20.09	15.81	32.20	22.90	16.81	21.30	22.93	20.00	26.90	21.24	20.27
Cichlidae	*Orechromis aureus*	19.79	20.60	14.95	20.55	2.12	14.48	18.49	30.00	17.56	25.63	24.37	16.81	18.52
Cichlidae	*Coptodon zillii*	17.71	19.60	7.01	16.21		11.45	15.97	4.78	12.20		3.05	9.73	10.30
Leuciscidae	*Alburnus mossulenssis*	2.78	7.04	8.88	6.72	3.39	2.36	5.04	2.61		5.63	4.06	5.31	4.33
Cichlidae	*Orechromis niloticus*	1.04	13.07	3.74		4.24	3.70	7.14		8.78		3.55		3.80
Leuciscidae	*Leuciscus vorax*	3.13	3.02	1.87	4.74	4.66	5.72			2.44	3.13	2.54	6.19	3.08
Cyprinidae	*Carasobarbus luteus*	2.43	2.51	2.34	3.95	2.12	4.38	1.68	3.91	4.88	3.75		6.19	3.08
Sulridae	*Silurus triostegus*	2.08	6.03	4.21			2.69	1.68		2.44	5.00		7.08	2.28

Family	Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Octo.	Nov.	Dec.	Total
Cyprinidae	*Cyprinus carpio*	2.43		1.87	2.77	2.97	1.35	0.84	1.30	5.37	3.75	2.03		2.09
Cyprinidae	*Carasobarbus sublimus*	1.39			1.98	2.54	2.02				2.50			0.95
Xenocyprididae	*Hemiculter leucisculus*						0.67	0.84	2.61			1.02	3.54	0.61
Poecilidae	*Gambosia holibrooki*					1.69			1.74		4.38			0.57
Cyprinidae	*Mesopotamichthys sharpeyi*		1.01		1.58	2.54	1.01							0.57
Leuciscidae	*Acanthobrama marmid*			0.93		1.69		1.68			1.25			0.46
Mastacembelidae	*Mastacembelus mastacembelus*	1.39								0.98		1.52		0.34
Heteropneustidae	*Heteropneustes fossilis*						0.67				1.25			0.15
Cyprinidae	*Cyprinon kais*			0.93	0.79									0.15

Table 3. The occurrence of fish species in Zachery Marsh from January to December 2022.

Category	Species	No. of species	Occurrence months
Resident fish species	*P. abu, C. gibelio, O. aureus*	3	12
	A. mossulensis, C. luteus	2	11
	C. zillii, L. vorax, C. carpio	3	10
Seasonal fish species	*O. niloticus, S. triostegus*	2	8
	C. sublimus, H. leucisculus	2	5
Occasional fish species	*M. sharpeyi, A. marmid*	2	4
	G. holibrooki, M. mastacembelus	2	3
	H. fossilis, Cyprinon kais	2	2

3.7. Fish Size Spectrum

The size spectrum of fish is a critical concern in wetlands that are prone to seasonal drought, particularly for commercially important species; drought causes the extermination of fish populations except that in lowland areas (Figure 6). The species *P. abu* size ranged from 6 cm to 17 cm, with the 10 cm length group being the most dominant, with 138 individuals of 784 fish representing the total catch of the species. The overall length of *C. gibelio* ranged from 7 cm to 24 cm, with 11 cm being the most prevalent group, comprising 83 individuals out of a total of 533 fish. The 81 fish samples of *L. vorax* that were gathered ranged in size from 10 cm to 31 cm; the dominant group was the 16 cm group, while the 23 cm and 29 cm groups were absent. The total length of 55 *C. carpio* fish ranges from 10 cm to 28 cm. The length group of 13cm was the most frequent, with nine individuals. The length groups in *81C. luteus* specimens ranged from 6 cm to 24 cm, with 12 cm being the most dominant group share in 14 individuals. The species *M. sharpeyi* caught 15 fish ranging in size from 12 cm to 26 cm, with the 16 cm length group being the most common and six groups being empty (13 cm, 17 cm, 19 cm, 21 cm, 22 cm, and 24 cm).

3.8. Ecological Indices

The variations in diversity, richness, and evenness indices were calculated monthly in Zachery Marsh during the study periods (Figure 7). The diversity index value ranged from 1.64 in August to 2.08 in June, with mean ±SD values of 1.91± 0.14. The evenness index varied from 0.69 in May to 0.91 in December, and the mean ± SD was 0.80 ± 0.06. Richness index values fluctuated from 1.47 in August to 2.28 in June, and the mean ± SD was recorded at 1.86 ± 0.23. The ANOVA analysis observed no significant differences ($P > 0.05$) among the three stations.

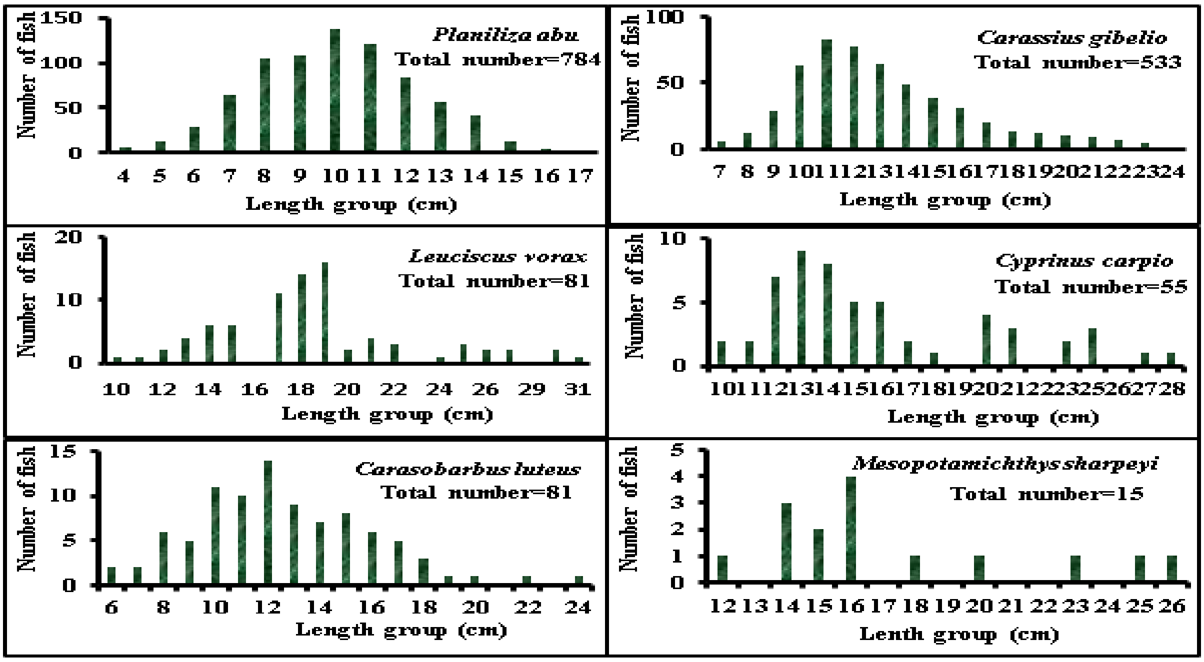

Figure 6. Length groups and distribution of fish size spectrums for the most important commercial fish species in Zachery Marsh.

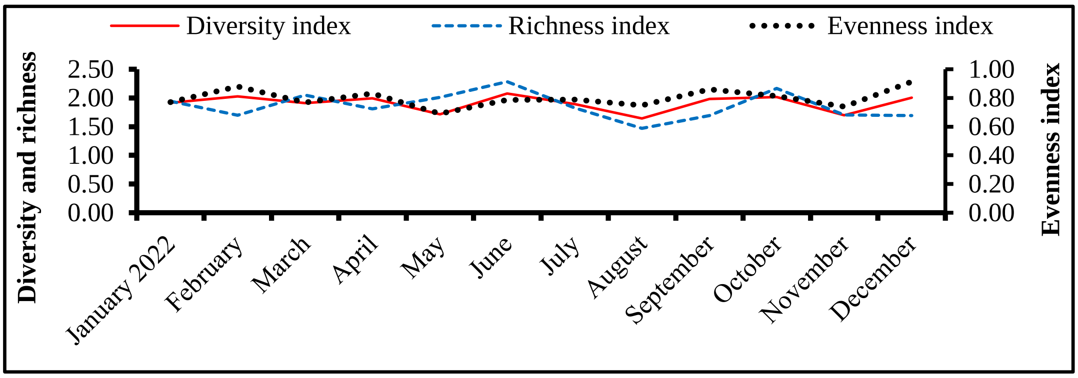

Figure 7. Monthly variation in the ecological indices in the Zachery Marsh.

4. Discussion

The decrease in discharge of the incoming waters of the Tigris and Euphrates rivers caused by the construction of many dams near their sources has resulted in significant reduction in water levels in the marshes, making them subject to long periods of drought throughout the year [21,22].

The marshes' ecosystems are closely related to the ecological variables that they are exposed to in general, for example, the temperature is mainly determined by the geographical location and has a direct impact on the drought and flooding processes that wetlands are exposed to [23]. The wetlands in southern Iraq suffer from a very hot and long summer compared to a rather short and temperate winter [24]. The situation has become worse with the impact of climatic changes, which have subjected the marshes to very long periods of drought compared to periods of flooding [25]. During the hot months, fish suffer from thermal stress, particularly in shallow areas rather than deep water in rivers [26].

The temperature has a greater impact in the middle marshes than salinity, which increased during drought periods. The current pH values are within the measurement ranges of Iraqi waters, which tend towards an alkaline trend [27]. The present marsh feeds on water through many artificial branches. These rivers allow the water to enter at a certain level and prevent the water from returning. This hydrological diversity preserves biodiversity from complete extermination due to drought, as the presence of low-lying areas (rivers, pools, and channels) act as ponds to preserve living organisms and

restore life when re-flooding, including the fish [1, 28]. The hydrological fluctuations have a major role in the building of fish assemblages in the seasonal wetlands of [29]. Broadly, the existence of different fish species in low regions in the dry season in one pool provides a refuge for the species in the dry conditions, in spite of the differences in their habitat preferences, as they live in one isolated, crowded pool to cross the difficult period to the next flood season [30].
Volcan and Guadagnin [29] reported that fish species composition might be determined by the diversity of habitat, wetland area, and longer hydroperiod; on the other hand, the effect of wetland area does not have a critical role in structuring fish assemblages. Other studies found that the change in the composition of the fish assemblage in the marshes is associated with a variation in the structure of the environment [31,32]. The present study found that the results in the fish assemblage composition were in line with the proposals of these studies, through the changes between flood and drought. In wetlands that are exposed to seasonal changes between drought and flooding, there are three strategies for fish reproductive in these wetlands (seasonal strategy, equilibrium, and opportunistic strategy), especially in the assemblage which occur in the temporary pools [1,19,20]. Fish in temporary pools must adapt to successfully survive a period of drought that is strict on evolution and life history. The reproductive strategy of fish that follow the seasonal strategy coincides with the flood season and includes all native Iraqi fish such as (*A. marmid*, *A. mossulensis*, *C. luteus*, *C. sublimus*, *L. vorax*, *M. sharpeyi*, *M. mastacembelus*, *P. abu* and *S. triostegus*). The equilibrium strategy includes the exotic species (*C. gibelio*, *C. gibelio*, *O. aureus*, C. *zillii*, *O. niloticus*), while the opportunistic strategy contains one species from the Poeciliidae (*G. holbrooki*), [19, 20]. In a seasonal environment like marshes, floodplains, wetlands, and rivers, fish assemblage composition is strongly correlated with abiotic factors that vary with water depth, hydroperiod, dissolved oxygen, temperature, and vegetation coverage [33, 34]. Regarding relative abundance, four small-sized tolerant species (*P. abu* 28.44, *C. gibelio* 20.27, *O. aureus* 18.52, and *C. zillii* 10.30%) were dominant in the Zachery Marsh [35]. This could be because small fish are more successful at offering shelter and food, especially in the seasonal shallow wetlands; on the other hand, the small individuals of fish in the vegetation marshes are more protective against predators compared to deep or open water where large fish live [36]. The species occurrence in the present study is consistent with the rest of the studies performed near the site of the present study and its vicinity in the north of Basrah
Province; most of them were small tolerant fish species, and their structure was a mixture of exotic species and Iraqi native species [1,37]. The marshes in southern Iraq are exposed to fluctuations in the dry season. In some years, there is a complete dryness of the temporary and permanent pools, so there is a complete extermination of the fish communities and the new fish offspring are small, but in other years, the permanent pools remain to replenish stocks. In the second case, the permanent pools that did not dry up are used as a stockpile to restore the communities of fish to their previous state, and the size spectrum of fish is relatively large [1,20,38]. The ecological indices are important to measure the biological communities, species abundance, monitor temporal and spatial effects of drowning and drought, decline of water depth, and pollution in freshwater environment, and their impacts on fish assemblage [39]. The Shannon-Wiener index values indicate a poor status, whereas the richness index refers to a half integrated into the Zachery marshes and measures the abundance and richness of the ecosystem, while the richness index estimates the richness of habitats by calculating the size of the sampling process and reducing the negative impacts during the collection of the samples [40]. Zhao et al. [41] pointed out that the evenness index estimates the relative diversity, and the habitat supports the congruous maximum values of species distribution densities in the assemblage. Generally, the ecological indices values in the Zachery marsh are identical to other studies conducted in the north Basrah province [1,9,37].

Conclusions

The hydrological changes have a crucial impact on the structuring of the fish assemblage in Zachery marshes, especially in the seasonal marshes that are subjected to fluctuations in water levels. Within these extreme conditions, the fish species developed several strategies for reproduction and survival. In the dry season, fish were forced to live in permanent pools under difficult, extreme conditions as a refuge, but their biological preferences were different. However, the consequence refers to the stability of diversity, richness, and abundance in the present seasonal marshes.

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