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(RESEARCH ARTICLE)

A study on age, growth, reproduction, and diet of *Leuciscus vorax* (Heckel, 1843) in Al-Diwaniya River, middle of Iraq

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Abstract

In this study, age, growth, sex ratio, size at first sexual maturity, gonad development (GSI) and food habit of *Leuciscus vorax* (Heckel, 1843) in Al-Diwaniya River, middle of Iraq were described between November 2016 and October 2017. *L. vorax* constituted about 6.4% % of the fish assemblage. The total length of all individuals ranged from 10.2 to 55.5 cm, the length-weight relationship was calculated as W= 0.007L 3.035 and isometric growth was observed. The mean value of the relative condition factor was 0.98. von Bertalanffy growth parameters were $L\infty$= 61.0 cm, K= 0.227 and t0= -0.196 years. The growth performance index (Φ) was found to be 2.93. The overall male to female ratio was 1:1.51. Length at maturity was 29 cm for males and 31 cm for females. The maximum gonado-somatic index was in January then dropped dramatically for both sex, suggest that the species may spawn in February. The feeding intensity and feeding activity were low during winter and high during summer. The species is a carnivore fed mainly on fish, shrimps, aquatic insects, and crustacean. In conclusion, it is found that the population of *L. vorax* reflects the expected and previously observed features of the species in natural waters, but it is necessary to activate the national law of fishing, exploiting and protecting aquatic resources to continuation the fish populations in the river as an economic resource.

Keywords: *Leuciscus vorax*; Growth; Reproduction; Diet; Al-Diwaniya River; Iraq

1. Introduction

The Cyprinid, *Leuciscus vorax* (Heckel, 1843) belongs to the Cyprinidae family which is regarded as one of the most widespread fish families in the world with 2963 available species and 1722 valid species [1]. *L. vorax* formerly placed in the genus *Aspius* and recently became within the genus *Leuciscus* [2]. The genus *Aspius* includes two species, one *L. aspius*, which lives in Europe, and *L. vorax*, whose geographical distribution is limited to the rivers and lakes of the Mesopotamian basin in Turkey, Syria, Iraq, and Iran[3, 4, 5, 6]. *L. vorax* is locally known as “Shillig” and widely distributed along the Mesopotamian basin in Turkey, Syria, Iraq, and Iran [6]. These fish are one of the most important species for artisanal fisheries, which are consumed locally as fresh fish. Mohamed *et al*. [7] stated that *L. vorax* was one of the dominated species in the artisanal fishery of Al-Swab marsh, constituted by 10.4% of the total fish landings during 2005.

The distribution of *L. vorax* have been reported in different freshwaters of Iraq including Habbaniyah lake [8], Shatt Al-Basrah canal [9], Razzazah lake [10], middle Euphrates river in Iraq [11-14], south marshes [15-17], Derbendikhan reservoir [18], Tigris river, Mosul [19], Dukan dam lake [20], Tharthar lake [21], Tigris river at Al-Kut Barrier [22] and Shatt Al-Arab river [23]. Moreover, the species was found in Euphrates river Syria [24, 25], Ataturk lake, Turkey [26], Karakaya reservoir, Turkey [27] and south Iran [28].

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Several biological studies conducted on *L. vorax* in different natural waters of Iraq, Turkey and Syria. Some authors have described the growth of the species [29, 8, 9, 30, 31, 26, 25, 32, 27, 33, 13, 34]. Other studies concentrated on the reproduction [8, 10, 35, 24, 26, 32, 36, 34]. Finally, some studies on the food habit of the species [8, 36, 37, 38, 15, 16, 13, 39].

However, there is no available information regarding the biological characteristics of the *L. vorax* in the Al-Diwaniya river, the middle of Iraq**.** Therefore, this study investigates some biological parameters, such as length frequency distribution, length-weight relationship, relative condition factors, age, growth rate, sex ratio, gonado-somatic index and food habit of *L. vorax* population in Al-Diwaniya river and compare the results with those of the species in other waters.

2. Material and methods

Fish species were collected monthly from the AL-Diwaniya river, middle of Euphrates River, Iraq [Figure 1] between October 2016 to September 2017. Specimens were caught using electrofishing equipment (provides 150-300V) and three types of nets. The seine net (3m long and 2.5m depth with a 20mm mesh size), gill nets (25m long with 20x20, 30x30 and 50x50mm mesh sizes) and cast net (9m diameter with 15x15mm mesh size). Fish were immediately preserved in an icebox for subsequent analysis.

Figure 1 Map of Al-Qadisiyah Province showing the sampling sites in Al-Diwaniya River

In the laboratory, total length (*TL*) was recorded to the nearest mm by using a measuring board and whole weight (*W*) was measured with an electronic balance and recorded to the nearest g. After the measurement, scales were extracted, cleaned, dried and mounted between two slides for binocular microscopic study [40]. The gut of each fish was removed and preserved in a specimen bottle containing 4% formaldehyde. The gonads were excised from the body cavity and weighed. Sex was determined by macroscopic observation of the gonads.

Parameters of the length-weight relationship were obtained by fitting the power function $W= a\ L^b$ [41] to length and weight data, where a and b are constants. The deviation of the allometric coefficient b from the theoretical value of isometric growth (b= 3) was tested by Student's *t*-test. The relative condition factor (K_n) was estimated from the equation; $K_n= W'/W$ [41], where W'= body weight and W= calculated weight from the length-weight relationship.

Total scale radius and the distance between the focus and their respective annuli were measured and the regression between fish length (L) and the radius of scale (S) was plotted. Back-calculated fish lengths were determined by the following formula: $L_n= a + S_n /S\ (L-a)$, where L_n is the length of the fish at age 'n', a is the intercept with the axis of the abscissa of the previous regression, S_n is the radius of the annulus 'n', S the scale radius and L is the length at the time of capture [42].

Growth was investigated by fitting the von Bertalanffy growth function to back-calculated fish lengths using Beverton and Holt method [43]. The von Bertalanffy growth function is defined as follows: $L_t= L_\infty (1- e^{-K(t-t_0)})$, where L_t is the total length of the fish at age t, L_∞ is the ultimate length an average fish could achieve, K is the growth constant which determines how fast the fish approach $L\infty$ and t_o is the hypothetical time at which the length of the fish is zero [43]. The growth performance index Φ [44] was calculated to provide a basis for the comparison of growth characteristics in terms of length: $\Phi=\log k+2\log L\infty$, where K and $L\infty$ are the von Bertalanffy parameters.

The population sex ratio was examined by using χ^2 good-ness-of-fit tests. The mean size at first maturity was taken as that at which 50% of individuals were mature. Gonado-somatic indices (GSI), calculated by expressing gonad weight as a proportion of total body weight [45], were plotted against the sample period by month to establish the timing and seasonality of spawning.

The food items were identified as the least taxon possible and counted. The frequency of occurrence (O) and the points (P) methods were used for analyzing the food items, and then using the index of relative importance (IRI) of Stergion [46]. The index combines the occurrence (O) and points (P):

IRI= O% × P% and IRI %= IRI / ΣIRI * 100

All the calculations were done by using Microsoft Office Excel 2010.

3. Results

The monthly fluctuations in the percentage of *L. vorax* in the river are shown in Figure 2. The abundance of the species was fluctuated from 2.0% in October to 10.2% in January. Generally, *L. vorax* constituted 6.4% of the fish assemblage in the study river.

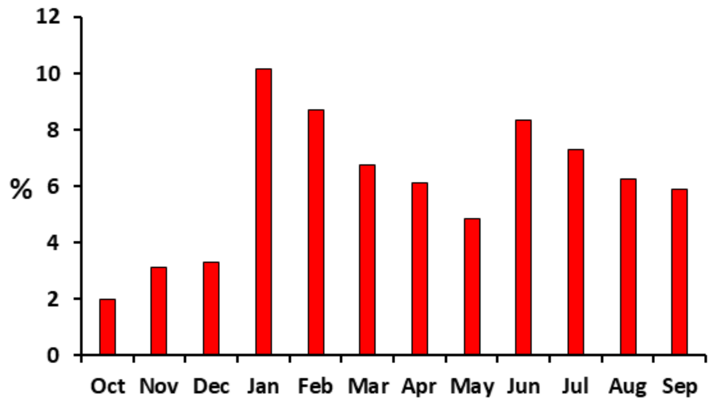

Figure 2 Monthly variation in the relative abundance of *L. vorax*

The total length-frequency distribution of all individuals for *L. vorax* caught by all fishing gears in this study is given in Figure 3. The length of the species ranged from 11 to 48 cm. Several modes can be recognized, but the highest one was 16 cm which constituted 8.9% from the catch, followed by 29 cm comprised 7.7%. Other modes were at different lengths. However, the lengths range of the species were mostly between 13-18 cm and 24-31, which constituted 35.6 and 34.8% of the catch, respectively.

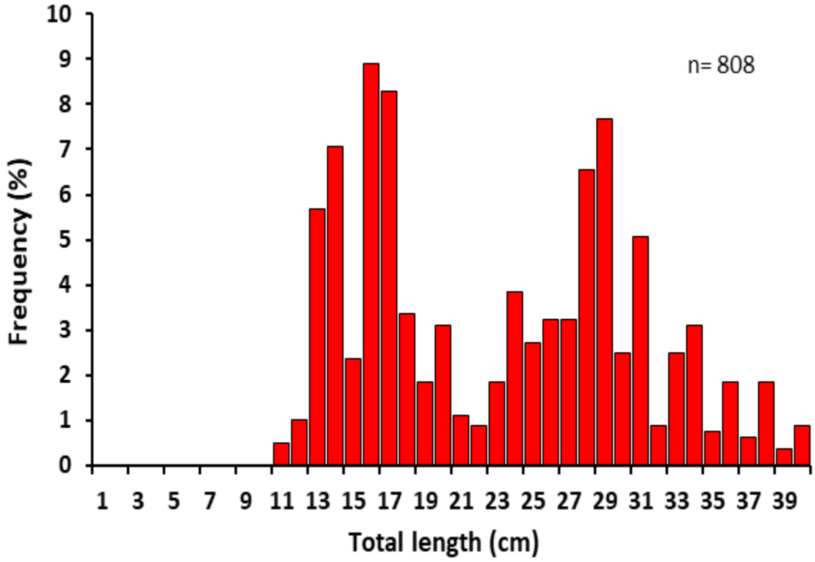

Figure 3 Length frequency distribution of *L. vorax*

The length-weight relationship of *L. vorax* for 501 specimens ranging from 10.2 to 55.5 cm in total length was represented with the following equation [Figure 4]: W= 0.007L3.035, (r2= 0.976). The exponent of the length-weight relationship was not significantly different from the value 3 (t-test= 3.424, P>0.05), which means an isometric growth pattern.

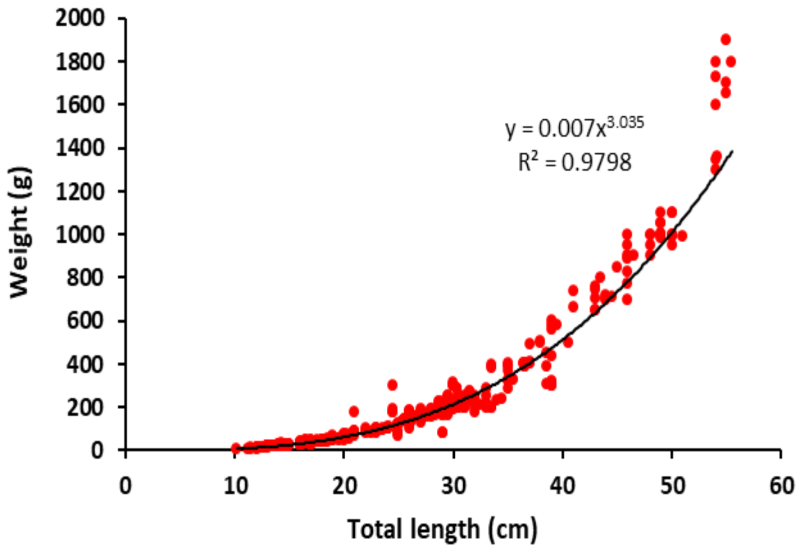

Figure 4 The length-weight relationships of *L. vorax*

Monthly fluctuation in the relative condition factor (K_n) of *L. vorax* for fish length groups 10.2-55.5 cm are presented in Figure 5. K_n was high in December and January and gradually declined until March followed by a rise in April. The range of K_n was 0.85 in March to 1.10 in December. The mean value of the relative condition factor in the overall sample was 0.98.

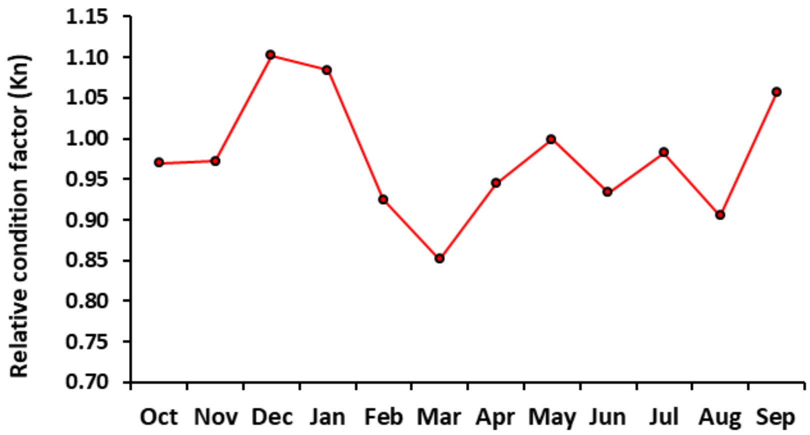

Figure 5 Monthly variation in relative condition factor (K_n) of *M. sharpeyi*

The scale radius (S) and total length (TL) relationship of *L. vorax* were fitted to a linear model, L =4.577+8.740S [Figure 6], which reflects the high degree of correlation between these two parameters ($r2$ = 0.880). The estimated age ranged from 1 to 8 years. Back-calculated lengths for *L. vorax* at different ages are given in Table 1. The mean calculated lengths of these eight ages were found to be 14.3, 23.4, 31.0, 38.2, 42.9, 45.9, 48.7 and 51.5 cm, respectively. The length annual increment gradually decreased with increasing age Occurrence of rapid growth in length was found during the first two years of life after which growth increment decreased gradually. The length annual increment varied from 27.7% during the first year of life to 5.3% during the 8th year of life. The growth model parameters of the species were $L\infty$ = 61.0, K = 0.227, t_o = - 0.196 and the index of growth performance (Φ) was 2.926.

The overall sex ratio for 446 fish sampled, 178 males and 268 females were (1:1.51) which biased in favor of females (χ^2= 18.2, P>0.05). Lengths at first maturity (L_{m50}) for males and females of *L. vorax* were 29 and 31 cm, respectively.

Monthly changes in the gonado-somatic index (*GSI*) were determined for males and females [Figure 7], and clear seasonal patterns were found. *GSI* values were high in January and gradually declined until May for males and June for females followed by a rise in July for females and October for males. The mean values of *GSI* for males varied from 0.12 in May to 4.30 in January, while for females ranged from 0.10 in June to 9.37 in January. There is a significant difference in the values of *GSI* between males and females among the study months (t-test= 2.14, P < 0.05).

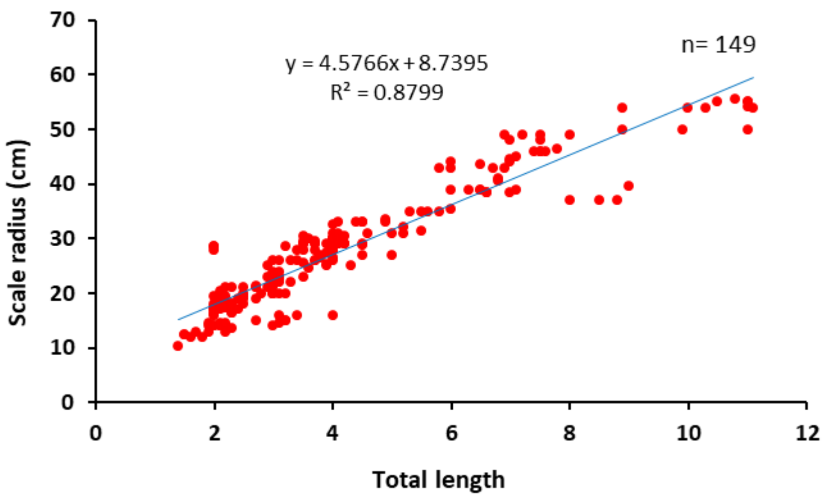

Figure 6 The linear relationship between total length and scale radius of *L. vorax*

Table 1 Mean observed and back-calculated total lengths of *L. vorax*

Age	No. of fish	Length at age (cm)								Observed length (cm)
		1	2	3	4	5	6	7	8	
1	34	13.9								15.0
2	31	14.1	23.6							23.5
3	41	14.1	23.2	30.5						31.1
4	12	16.0	23.3	32.3	38.3					38.4
5	8	14.9	23.9	31.5	37.4	42.8				43.0
6	8	14.4	23.1	31.1	38.1	43.3	45.9			46.4
7	7	14.1	23.7	34.8	39.5	43.0	45.9	48.9		49.4
8	8	14.3	24.1	34.0	38.0	42.5	45.7	48.5	51.5	52.5
Mean length (cm)		14.3	23.4	31.0	38.2	42.9	45.9	48.7	51.5	
Annual increment (cm)		14.3	9.2	7.6	7.2	4.7	2.9	2.8	2.7	51.45
% Growth increment		27.7	17.8	14.7	14.0	9.1	5.7	5.5	5.3	

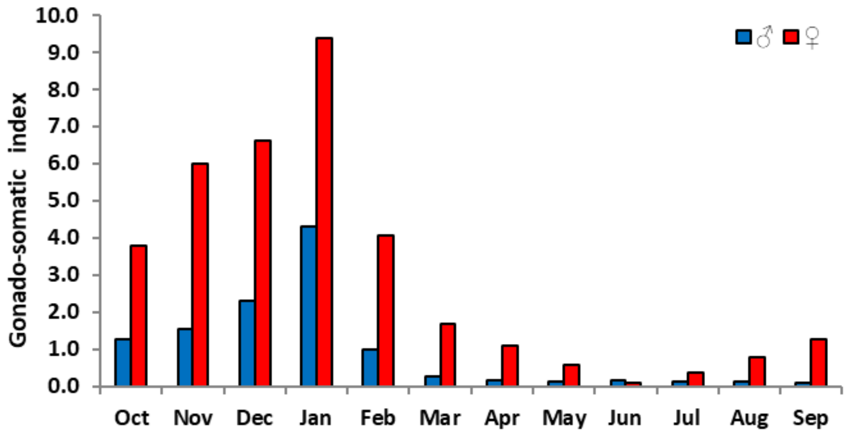

Figure 7 Monthly variations in the GSI of *L. vorax*

The feeding intensity varied from 5.0 points/fish in December to 12.8 points/fish in September, while the feeding activity of the species ranged from 33.4% in December to 88.5% in May [Figure 8]. In general, both feedings were low during winter and high during summer, as there were significant correlations between water temperature and both feeding activity and intensity, r= 0.853 and 0.823, $P < 0.05$, respectively.

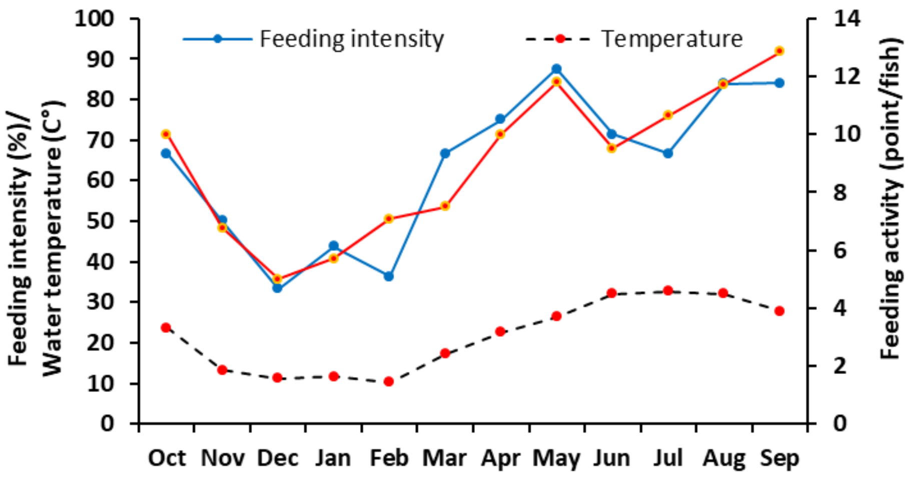

Figure 8 Monthly variations in water temperature (C°) and feeding intensity and activity

Fish were divided into two size groups, small fish (<20 cm) and large fish (>20 cm). Small individuals of *L. vorax* in the river fed on fish, shrimps, aquatic insects, algae and crustaceans [Figure 9]. The peak contribution of fish was 59.9% (*IRI*%) in February, shrimps 38.5% in March, algae 18.1% in October, crustaceans 17.8% and aquatic insects 14.4% in July. The overall diet composition of small individuals was comprised of fish (49.5%), shrimps (24.9%), aquatic insects (9.5%), algae (8.1) and crustacean (8.0%).

Figure 10 also illustrates monthly variations in the relative importance index (*IRI*%) of food items of large individuals of *L. vorax* in the river. Fish were the most important food items, their contribution varied from 35.2% in January to 78.2% in November. Shrimps ranked second were consumed in October and March at 2.2% and 40.9 % respectively. Aquatic insects ranked third and more were eaten in January (38.2%). Finally, crustacean varied from 1.3% in September to 18.4% in October. The overall diet composition of large individuals of *L. vorax* was comprised of fish (58.1%), shrimps (24.3%), aquatic insects (11.0%) and crustacean (6.6%).

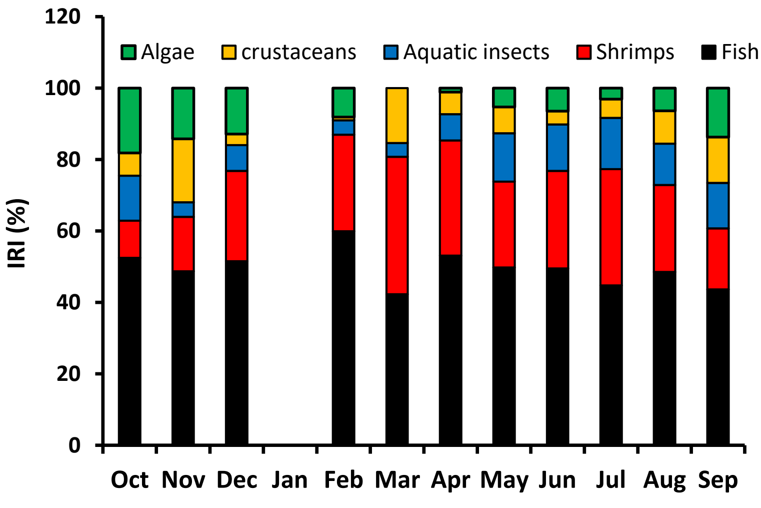

Figure 9 Monthly changes in *IRI*% of food items of small individuals of *L. vorax*

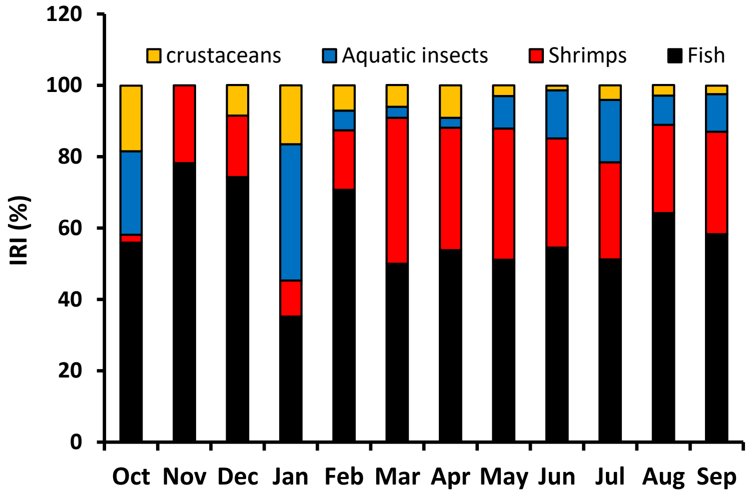

Figure 10 Monthly changes in *IRI*% of food items of large individuals of *L. vorax*

4. Discussion

The study revealed that *L. vorax* comprised 6.4% of the fish assemblage in Al-Diwaniya river which was higher than the values reported for the species from some other Iraqi waters, 4.3% of fish in Euphrates River at Al-Mussaib Power Station [11], 4.2% of fish population in Al-Huwaizah marsh [15], 1.8% of fish population in East Hammar marsh [17], 1.6% of fish in Euphrates River between Al-Hindyah Barrier and Kufa [47], 0.7% of fish in Al-Hilla river [12], 3.1% of fish population in Al-Chybayish marsh [48], 1.0% of fish population in Dukan dam lake [20], 5.1% of fish population in south part of Tharthar lake [21] and 0.3% of fish population in Shatt Al-Arab river [23]. However, this percentage was lower than that documented from other Iraqi waters, 15.3% of fish population in Euphrates river at Al-Hindyah Barrier [13], 7.3% of fish population in Tigris river at Al-Kut Barrier [22] and 11.7% of fish population in Euphrates river near Al-Hindyah Barrier [14].

The length sizes of *L. vorax* in the present study, 11.0 to 55.5 cm were within the range of the total length of the species recorded from other waters such as in Al-Habbania lake, 11.4-55.1 cm [8], in Al-Hammar marsh, 18.3-40.3 cm [29], in East Hammar marsh, 3.7-55.6 cm [48] and in Shadegan Wetland, Iran, 11.5-40.5 cm [33]. Conversely, this length size was lower than those recognized from other waters, 4.0-62.0 cm in Garmat Ali river [35], 16.7-62.2 cm in the artificial lake, west of Baghdad [49], 19-70 cm in Euphrates river, Syria [25]. The length of fish ranges may be different between habitats due to the different fishing methods used or to different environmental conditions, food supply, population density or competition with exotic species [50].

The growth of *L. vorax* in the present study was isometric pattern since the regression coefficient (b) in the length-weight relationship equal 3.035, namely, there is no change of body shape as an organism grows and that weight increases as the third power of length [51]. Similar isometric growth for *L. vorax* populations were reported in different locations, like in Al-Habbania lake, 3.060 [8], in the Shatt Al Basrah Canal, 3.077 [9], in Euphrates river, Syria, 3.130 [25], 2.9706 in Karakaya reservoir, Turkey [27], 3.03 for males and 3.02 for females in Shadegan Wetland, Iran [33], 3.085 in East Hammar marsh [34]. Karnal *et al.* [52] and Cuadrado *et al.* [53] stated that the value of (b) in the length-weight relationship can be affected by major environmental factors, the size range of fish, food supply, stomach fullness and disease and parasite loads.

The relative condition factor is regarded as a measure of a condition deviation, health, or fullness of the fish from the height-to-weight ratio within a group [42]. K_n was high in December and January and gradually declined until March followed by a rise in April. The general pattern of relative condition factor of *L. vorax* was high in December and January coincided with the growth of the gonads, then gradually declined until March which corresponded with the spawning time of the species, after which improved steadily during summer months may be related with the highest period of feeding and the recovery of gonads. The correlation coefficient between gonads somatic index for males and females *L. vorax* and condition factor of the species were positively (r= 0.61 and 0.56, p> 0.01), respectively. Other studies reported variety values of condition factor for the species, 1.01-1.51 in Hammar marsh [29], 0.74-1.18 in Al-Habbaniyah lake [8], 0.76 in Tharthar lake [10], 1.8 in Diyala river [53], 0.7 in Euphrates River, Syria [25] and 0.74 in

Tigris river, Tikrit [32]. The variations in the condition factor of fish primarily reflect its nourishment status and state of sexual maturity [54].

The growth information of *L. vorax* in the present study and those documented from other waters are given in Table 2. It can be seen that the number of ages of the species in Al-Diwaniyah river is consistent with that of most other environments. The growth rates of the species in the present study were within the range of the growth of the species reported by other authors. Asymptotic length ($L\infty$) of *L. vorax* in Al-Diwaniya river was higher than that recorded for the species in the other waters, Al-Hammar marsh [29], Euphrates river, Al-Mussaib [31], Diyala river [53] and East Hammar marsh [34]. However, it was lower than the values that can be reached by the species in Al-Habania Lake [8] and Karakaya reservoir, Turkey [27]. The growth performance index (Φ) of the species in the present study (2.612) was intermediate with other values for the species in other waters (Table 2). The highest value of (Φ) was recorded in the Karakaya reservoir, Turkey by Duman and Gül [27]. Some differences between the growth characteristics among populations in different regions involving the same species may be attributed to variation in environmental conditions such as water temperature, diversity, availability of food items and over-exploitation of natural stocks [55, 56].

Table 2 Growth characteristics comparison of *L. vorax* in different environments

References	$L\infty$ (cm)	Mane total length at each age (cm) 1	2	3	4	5	6	7	8	ϕ	Environments
[8]	91.0	12.9	21.8	29.8	36.8	43.0	48.5	53.4	-	3.0	Al-Habania Lake
[29]	52.3	8.2	18.1	25.7	31.5	36.1	-	-	-	2.8	Hammar marsh
[31]	52.5	16.0	24.8	30.7	35.4	40.2	42.0	44.6	-	2.9	Euphrates river, Al-Mussaib
[53]	45.7	12.0	17.4	22.0	26.9	31.0	-	-	-	-	Diyala river
[27]	92.7	-	-	-	-	-	-	-	-	3.11	Karakaya reservoir
[13]	-	15.0	21.0	29.2	33.5	38.0	55.0	62.0	-	-	Euphrates river, Al-Hindia dam
[34]	57.0	16.4	24.5	31.2	37.4	42.5	47.2	50.8	53.5	2.97	East Hammar marsh
Present study	61.0	14.3	23.4	31.0	38.2	42.9	45.9	48.7	51.5	2.92	Al-Diwaniya river

The overall sex ratio of *L. vorax* in the present study was (1:1.51) which biased in favour of females. Similar deviations in the sex ratio have been observed in populations of *L.vorax*. Mutlak [57] stated that the species in East Hammar marsh was composed mostly of females (sex ratio: 1:1.62). Also, the ratio between the sexes of *L. vorax* in Atatürk dam lake, Turkey was poised mostly of females, the sex ratio was 1:1.75 [26]. However, Al-Saleh *et al*. [25] and Wahab and Al-Ani [58] stated no significant differences between sexes of the species in Euphrates River, Syria and Eastern drainage/Balad, Iraq, respectively. Although, the sex ratio for fish populations depends on different factors like differences in mortality rates between sexes, spawning migration and differences in growth between sexes, the selectivity of fishing gears and differences in sampling and different habitats [50, 55]. Lengths at first maturity (L_{m50}) for males and females of *L. vorax* in the present study were 29 and 31 cm, respectively. Al-Selah *et al*. [24] observed that females of the species attained the first maturity at 40 cm and males at 38 cm in the Euphrates river, Syria. Wahab and Al-Ani [58] found that lengths at first maturity (L_{m50}) for males and females of *L. vorax* were 29 and 31 cm, respectively in Eastern drainage/Balad, Iraq.

Gonado-somatic index (GSI) is a good indicator to determine the spawning time in fishes, and common parameter widely used by the biologists to predict of spawning season of fish. GSI values of *L. vorax* present study were high in January for both sexes and gradually declined in February suggest the possible spawning period of *L. vorax*. Shafi and Jasim [8] pointed that *L. vorax* spawning started in January at Al-Habania lake, whereas Epler *et al*. [10] reported that spawning of the species started in February in Al-Habania and Tharthar lakes. Oymak *et al*. [26] stated that the higher GSI values of *L. vorax* population were observed in the samples of March, April, and May for females and males, and concluded that the spawning took place in April and extended to May in Atatürk dam lake, Turkey. Al-Selah *et al*. [24] mentioned that the spawning of the species lasted from the end of February to the middle of March in the Euphrates river, Syria. Abdullah *et al*. [36] found that the maximum values of GSI for females and males occurred in February in Al-Huwaizah marsh. Several authors refer to the effects of water temperature on the developing gonad and assign it to the spawning time of *L. vorax* in different waters [26, 25, 36]. Nikolsky [50] pointed out that the spawning characteristic of a fish varies concerning species and ecological characteristics of the water system in which they live.

Monthly trends in the feeding activity and intensity of *L. vorax* were related positively with a water temperature of the river (r< 0.820), the highest values of the criterion were recorded in summer and the lowest in winter. During this study, the water temperature of the river ranged between 10.2 and 32.8 ºC. It was about 10.2-13.3 ºC in winter and increased up to 32.0-32.8 ºC in summer. Similar observations were reported by Hussein and Al-Kanaani [38] and Khaddara [13] who found the feeding rates of *L. vorax* were low during winter and high during summer in Al-Hammar marsh and Euphrates river, respectively. Temperature is an important factor that regulates the biological and chemical activities in the aquatic environment as well as the metabolism and growth of fish [50]. It is generally known that feeding activity of Cyprinids decreases with decreasing in the water temperature [59].

Diet of small and large individuals for *L. vorax* in the present study consisted of fish, shrimps, aquatic insects, and crustaceans, this means that the species is carnivorous food habit depends chiefly on animal food sources making up 92%. Various authors studied the food habit of *L. vorax* is different in different parts of Iraqi waters have reported similar finding [8, 29, 38, 17, 15, 32, 13, 39]. Fish dominated the food items consumed by *L. vorax* in all studies. Fish accounted for 66.7% in the diet of the species in south marshes [17], 47.4% in Al-Huwaizah marsh [15], 52.3% in Garma river [60] and 92.2% in East Hammar marsh [39].

5. Conclusion

It is found that the population of *L. vorax* reflects the expected and previously observed features of the species in natural waters, but it is necessary to activate the national law of fishing, exploiting and protecting aquatic resources to continuation the fish populations in the river as an economic resource.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

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