

Analysis of the Biological Features of the Blue Tilapia, *Oreochromis aureus* in the Garmat Ali River, Basrah, Iraq

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ABSTRACT- The blue tilapia, *Oreochromis aureus* (Steindachner, 1864) is exotic fish and became widely distributed throughout different natural waters of Iraq during the last years. The present study describes the length compositions, age, growth, reproduction and food habit of the species in the Garmat Ali River from September 2018 to August 2019. A total of 1050 specimens were caught using gill nets, cast net, and electro-fishing. The lengths of *O. aureus* ranged from 6.6 to 22.9 cm, and the most dominant lengths were 14.0 to 18.0 cm representing 61.6% of the catch. A positive allometric growth pattern was observed for males ($b= 3.317$), females ($b= 3.231$) and all individuals ($b= 3.283$). There were three peaks for relative condition factor (K_n) that appeared during October, April, and July for both sexes. The age estimated on the basis of scales showed that the population comprised of 1 to 5 years. The parameters of the von Bertalanffy growth curve were $L_{\infty}= 27.6$ cm, $K= 0.193$ and $t_0= 1.18$. The growth performance index (ϕ) of *O. aureus* was computed as 2.17. The overall sex ratio (male: female) was 1:1.04. Females attained sexual maturity at a lower size than males with mean size at first maturity determined as 6.6 cm for females and 9.2 cm for males. Two peaks of the gonado-somatic index were shown, the higher one in April and the lower one in September in both sexes. The estimated fecundity ranged from 352 to 1033 eggs in the fish ranging from 12.2 to 20.5 cm in length. *O. aureus* is an opportunistic feeder that will successfully utilize whatever food source is available, its diet comprised of detritus (43.1%), diatoms (23.9%), algae (22.8%), macrophytes (7.1%) and crustaceans (6.0%). The results highlighted basic biological features on invasion fish species which can assist in fisheries management and conservation of the fish species in Iraqi waters.

Keywords-- Blue tilapia, age and growth, reproduction, food habit, Garmat Ali River, Iraq

1. INTRODUCTION

Oreochromis aureus (Steindachner, 1864), commonly known as blue tilapia is a species of fish in the Cichlidae family. The members of this family are generally known as tilapia (Cichlid). Tilapia is native to northern and western Africa, the Middle East, central and south America, and southern India [1]. This family represented 250 genera and 1720 valid species [2]. Tilapia consists of three important genera namely *Oreochromis*, *Sarotherodon* and *Coptodon* (*Tilapia*), each includes many species including blue tilapia *O. aureus*, Nile tilapia *Oreochromis niloticus*, Gillean tilapia (*Sarotherodon galilaeus*) and redbelly tilapia *Coptodon zillii* [3]. All tilapia species are nest builders; fertilized eggs are guarded in the nest by a brooding parent. Species of both *Sarotherodon* and *Oreochromis* are mouth brooders; eggs are fertilized in the nest but parents immediately pick up the eggs in their mouths and hold them through incubation and for several days after hatching. In *Oreochromis* species, only females practice mouth brooding, while in *Sarotherodon* species either the male or both male and female are mouthbrooders [4].

O. aureus has mainly been introduced into different waters through stocking, but also via aquaculture and aquatic vegetation control. It is reared widely all over the world, and escapes or releases from aquaculture facilities, zoological parks, and aquariums are common [5]. *O. aureus* is primarily a fresh and brackish water fish that occurs in a wide range of habitats such as streams, rivers, lakes, and ponds, but it has a high tolerance for saltwater at up to 20‰. The lower lethal water temperature for most tilapia species is 10-11°C for a few days, but the *O. aureus* tolerates temperatures to about 8°C [4].

Tilapia species are exotic fish to Iraqi waters and early records show that *Tilapia (Coptodon) zilli* was present in the Euphrates River near Musaiab City, Centre of Iraq [6, 7]. Later two cichlids species, *C. zilli* and *O. aureus* were recorded further south in the main outfall drain, Basrah [8] and *O. niloticus* in the Shatt Al-Arab River [9], and became widely distributed in different natural waters of the country [10-13].

O. aureus now well established and easily becomes one of the dominant species in some Iraqi waters. The species constituted 12.58% of fish assembly in the Shatt Al-Arab River [14], 2.64% of the fish assemblage in Garmat Ali River [15], 11.42% of fish assemblage in the Al-Diwaniya River, middle of Iraq [16], 18.86% of fish structure in the Al-Swab River, a tributary of Shatt Al-Arab River [17] and 11.7 % of fish assemblage in the middle part of Shatt Al-Arab River [18].

Some biological characteristics of *O. aureus* have been carried out by several investigators in different natural waters of the world [19-26, 1]. In Iraq, the growth and food habits of *O. aureus* have been investigated in some waters. [27, 28] studied the food habit of *O. aureus* in the north of Shatt Al-Arab River and Chybayish marsh, respectively. [29] described the growth of *O. aureus* in the Euphrates River at the Al-Hindia barrier, middle of Iraq. [30] investigated the trophic interaction of *O. aureus* with two other cichlids species in the Euphrates River. [31] studied the food habit and growth of *O. aureus* in the Tigris River, south of Baghdad.

The aim of this study was to collect information on age, growth, length-weight relationship, relative condition factor, sex ratio, gonado-somatic index, fecundity and food habit of *O. aureus* collected from Garmat Ali River, south Iraq for the first time, in order to investigate the causes of its rapid spread in this waters and to gather data on which to design a plan for the control of this exotic species.

2. MATERIALS AND METHOD

The study area includes the Garmat Ali River, a waterway that connects the East Hammar marsh to the Shatt Al-Arab River, situated in the north of Basrah city (Fig. 1). Its length is about 6 km with a width of 280 m and mean depth of 9 m. The river is affected by the tidal current of the Arabian Gulf through the Shatt Al-Arab River. The predominant vegetation on the banks was *Phragmites australis* and *Typha domingensis*, whereas *Ceratophyllum demersum* was dominant in the deeper areas. Samples were collected monthly along the river from September 2018 to August 2019.



Figure 1: Map of the Garmat Ali River with locations of study sites.

Fish were caught by drifted gill nets (200-500 m length, with 15x35 mm mesh size), fixed gill nets (100-300 m length, with 15x35 mm, mesh size), cast net (9 m diameter, with 15x15 mm mesh size) and electro-fishing by generator engine (providing 300-400V and 10A). After capture, the fish were preserved in an icebox for subsequent analysis.

In the laboratory, fish were identified and weighed to the nearest g and measured to the nearest 0.1 cm total length individually. Scales were extracted from a standard area between the lateral line and dorsal fin of the fish, cleaned, dried and mounted between two glass microscope slides for age estimation. Fish were then dissected and the stomachs were removed and preserved in 4% formaldehyde. Gonads were subsequently removed from the body cavity and weighed. Sex was determined by macroscopic observation of the gonads. To determine the absolute fecundity of the fish, ovaries of 18 matured ovaries with visible eggs were preserved in Gilson fluid during March-April 2019, and the estimation of fecundity based on the gravimetric method [32]. Absolute fecundity was estimated by weighing all the eggs in the ovary and also by counting three subsamples of eggs from different parts of the ovary. The regression of fecundity on both length and weight was calculated.

The length-weight relationship was determined by applying the equation $W = \alpha L^b$, where W is the total body weight (g), L is the total length (cm), α is the intercept and b is the slope [33]. The Student t-test was used to compare the value of the slope (b) with 3 [34]. The relative condition factor (K_n) was estimated using the following formula, $K_n = W''/W$ [33], where W'' = the observed weight of each individual and W = the expected weight using the length-weight relationship.

Scales were examined using a micro-projector (magnification 20X) to age determination, and to measure the total scale radius and the distance from the focus to each annulus. The body-scale relationship was best described by the linear equation $L = a + bS$ where L is the total fish length in cm, S is the scale radius in cm and a is the intercept on the y-axis and b the slope of the regression line. Hence, the lengths were back-calculated with the equation $L_n = a + S_n / S (L - a)$ [35], 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 is the scale radius at capture and L is the length at capture.

The von Bertalanffy growth equation for length was fitted to the back-calculated mean lengths using Beverton and Holt method [34]: $L_t = L_\infty(1 - e^{-K(t-t_0)})$, where L_t is total length at age t , L_∞ is asymptotic length, K is the growth coefficient and t_0 is hypothetical age at which the length is zero. Based on von Bertalanffy growth parameters, the performance index (Φ) was calculated as $\Phi = \log_{10} K + 2 \log_{10} L_\infty$ [36].

The sex ratio compared to 1:1 using a Chi-square test (χ^2). The mean size at first maturity was taken as that at which 50% of individuals were mature. The gonado-somatic index (GSI) was calculated by expressing the gonad mass as a percentage of body mass [37]: $GSI = \text{gonad weight/body weight} \times 100$

Later, stomach was opened, gives the degree of fullness, and then emptied into a Petri dish to examine different food items using a research microscope. The stomachs were scored 0, 5, 10, 15 and 20 points according to its fullness as described by [38]. The feeding index was determined after [39]. The vacuity index was calculated as the number of empty stomachs divided by the number of stomachs analyzed [40]. The different food items were identified according to [41], [42] and [43]. The results were analyzed by employing two methods, the percentage of points (P%) and frequency of occurrence (O%) methods [44]. An estimate of the index of relative importance (IRI%) of each food category was obtained by combined the two methods [45]:

$$IRI = O\% \times P\% \text{ and } IRI \% = IRI / \sum IRI * 100$$

The obtained data were analysed using the computer programmed Microsoft Excel, ver., 2010.

3. RESULTS

3.1 Seasonal variations in length-frequency distributions

Figure (2) shows the seasonal length-frequency distributions of *O. aureus* in the present study. The sample composed of 1050 specimens, ranged from 6.6 to 22.9 cm in total length, the smallest fish was caught in March (spring) and the largest one in August (summer). The smallest fish caught during autumn was 12.0 cm and the largest one was 22.3 cm. The highest frequency of catches belonged to the length group 17 cm constituting 22.4%, while the length groups from 15 to 19 cm prevailed the catch and formed 77.1%. Lengths of fish during winter ranged from 7.8 to 21.0 cm, and the most dominant length groups observed were those of 9 to 11 cm representing 41.1% of the catch, while sizes 14 to 16 cm accounted for 33.3%. The small fish caught during spring was 6.6 cm and the large one was 20.5 cm. The fish lengths 12 to 15cm comprised 56.1 of the catch during this season. Sizes of *O. aureus* during summer ranged from 12.7 to 22.9 cm, and the dominant length group was 16 cm, formed 20.4% of the catch in this season, while the length groups 14.0 to 18.0 cm constituted 81.5%. The overall lengths of *O. aureus* ranged from 6.6 to 22.9 cm, and the most dominant length groups observed were those of 14.0 to 18.0 cm representing 61.6% of the total number.

3.2 Length-weight relationship and relative condition factor

The graphical representation of the estimated length-weight relationships for females, males and all individuals of *O. aureus* is given in Figure 3. Using a t-test for equality of two regression coefficient, a significant difference ($t = 3.7$, $p < 0.05$) of growth was observed in males and females. Thus this suggested the use of one model for males and another for females. The descriptive statistics for the calculation of length-weight relationships of all groups are presented in Table 1. The statistical test of $b = 3$ being statistically significant, indicating positive allometric growth for all groups. Also, the corresponding significant correlation coefficients (r^2) indicating a length-weight relationship (in log scale) strongly linear in all the cases.

Monthly changes relating to the mean relative condition factor (K_n) of *O. aureus* were determined for each sex (Fig. 4), although there are no significant differences in the relative condition index (K_n) between them ($t = 0.02$, $p > 0.05$). The mean values of K_n for males and females were 1.00 ± 0.03 and 1.00 ± 0.05 , respectively. The

highest values of K_n for males and females were in July, 1.07 and 1.12, respectively, while, the minimum values of K_n for all individuals were in February, 0.95 and 0.92, respectively. However, there are three peaks for relative condition factor observed in October, April, and July for both sexes.

3.3 The age composition and growth

The relationship between the fish length (L) and the scale radius (S) of *O. aureus* fitted to a linear model (Fig. 5), which was $L = 2.497 + 5.767 S$, $r^2 = 0.985$. The estimated age ranged from 1 to 5 years. Ages 2 and 3

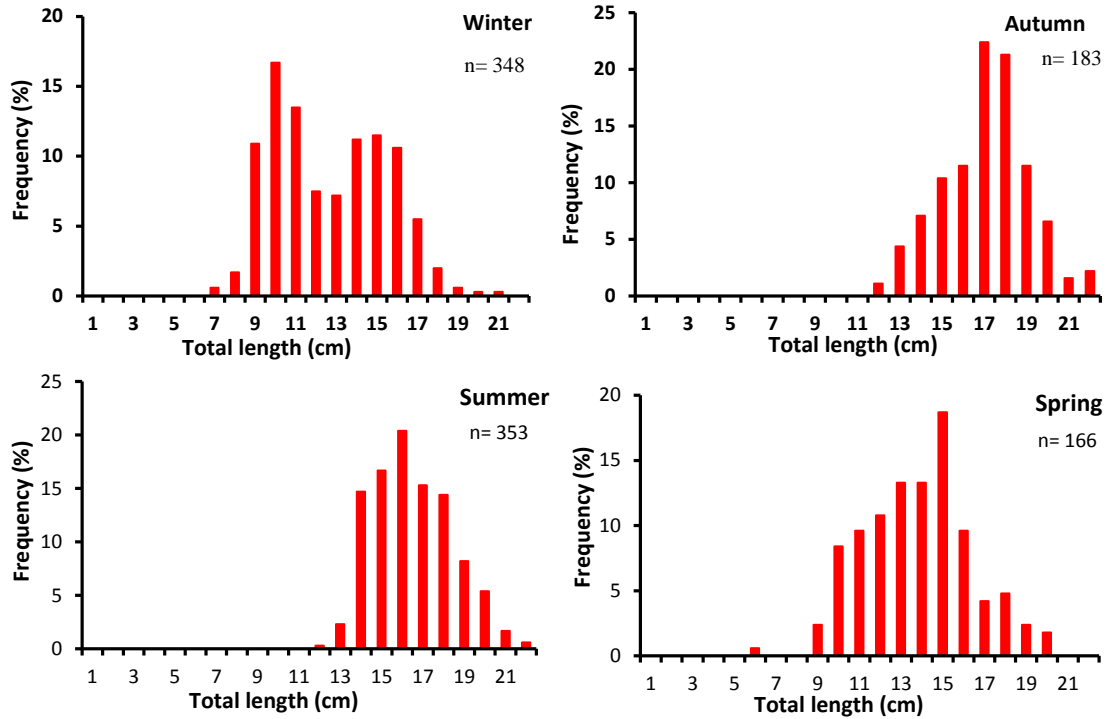


Figure 2: Seasonal length-frequency distributions of *O. aureus*

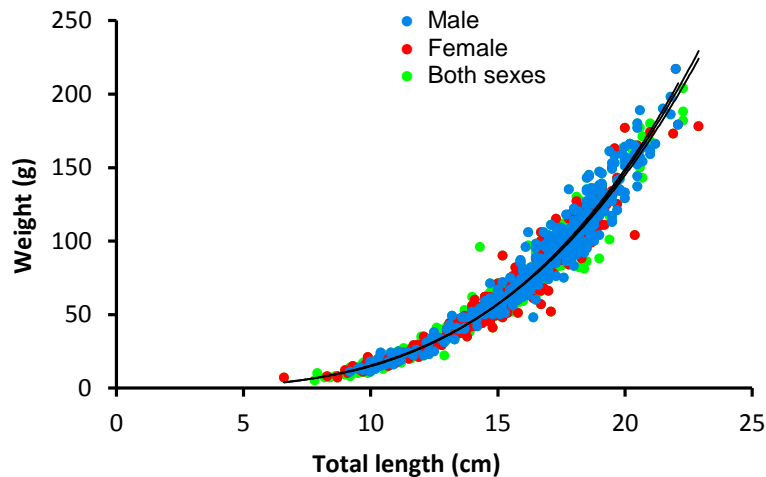


Figure 3: The length-weight relationships of males, females and all individuals of *O. aureus*

Table 1: The descriptive statistics of length-weight relationships of *O. aureus*

Sex	N	Total length (TL, cm)			Regression coefficient			t-test
		Mean±S.D	Min.	Max.	a	b	r ²	
Male	370	16.6±2.776	9.2	22.1	0.0073	3.3171	0.9676	10.019*
Female	386	15.3±2.456	6.6	22.9	0.0079	3.2313	0.9654	7.4076*
All individuals	1050	15.3±3.023	6.6	22.9	0.0079	3.2834	0.9710	16.165*

Note: N=sample size; S.D=standard deviation; *t-test is significant, $p < 0.05$

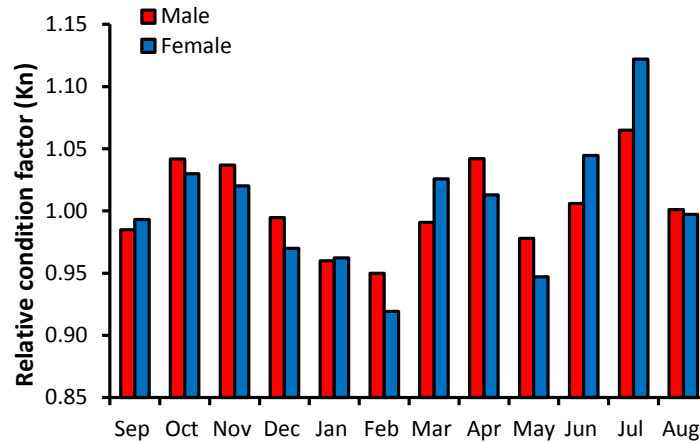


Figure 4: Monthly variations in relative condition factor of *O. aureus*

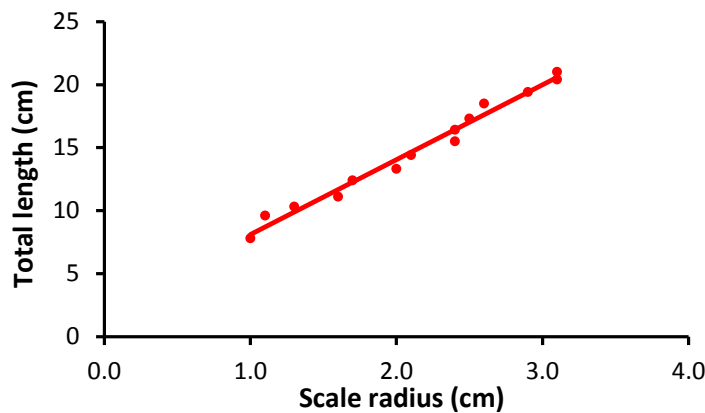


Figure 5: The relationship between fish length and scale radius of *O. aureus*

were the most numerous both for the total population (62.7%) and 23.1, 12.1 and 2.2% for ages 1, 4 and 5, respectively. The mean size of fish at the time of formation of the first annulus was TL= 2.5 cm.

The average back-calculated lengths of the pooled data at different age classes have been calculated as given in Table 2. The mean lengths estimated at ages 1 to 5 years were found to be 9.5, 12.6, 15.3, 17.5 and 19.2 cm, respectively. The back-calculated length at annulus formation suggested that *O. aureus* increased in length by 49.4% in age 1 and 9.1% at age 5.

Using back-calculated lengths at age (Table 2), we estimated the von Bertalanffy growth equation parameters as follows:

$$L_t = 27.6(1 - e^{-0.193(t+1.18)})$$

The growth performance index (Φ) of *O. aureus* was calculated as 2.17

Table 2: Mean back-calculated total lengths at age of *O. aureus*

Age	Length at age (cm)					No. of fish
	1	2	3	4	5	
1	10.5					21
2	9.6	13.0				27
3	8.7	12.7	15.6			30
4	9.9	13.6	16.5	18.7		11
5	8.6	11.0	13.9	16.2	19.2	2
Mean length (cm)	9.5	12.6	15.3	17.5	19.2	
Annual increment (cm)	9.3	3.1	2.8	2.1	1.8	
% Growth increment	49.4	16.2	14.3	11.0	9.1	

3.4 Reproduction

In the study, a total of 756 fish from *O. aureus* were analyzed, 386 (51.1%) were female and 370 (48.9%) were males. Females were more abundant than males throughout the year except in September, November, and May-July. The overall sex ratio was 1:1.04 (male: female), and did not differ significantly of the sex ratio 1:1 ($X^2 = 0.34, P > 0.05$). No fish less than 6.6 cm was caught, and this fish was female at the maturity stage. Also, the smallest male (9.2 cm) in the samples was sexually mature.

The GSI value of male *O. aureus* ranged from 0.07 in February to 2.92 in April (Fig. 6). Fish caught from October to January having low GSI values. For females, the GSI values varied from 0.23 in November and July to 9.11 in March. Low GSI values were observed in the months of October to February and July. Two peaks of the gonado-somatic index were shown, the higher one in April thereafter as a sign of the continuous release of eggs, and the second in September in both sexes (Fig. 6).

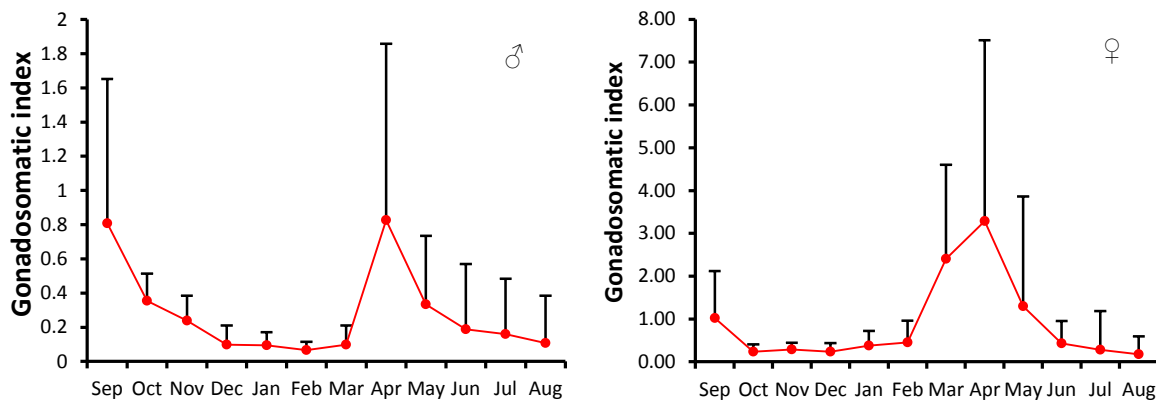


Figure 6: Monthly variations in the GSI of *O. aureus*

A total of 18 gravid females of *O. aureus* were examined for its fecundity. The fecundity ranged between 352 to 1033 eggs, with a mean value of 759 ± 193.8 in the fish ranging from 12.2 to 20.5 cm in length and 29 to 165 g in weight. Various relationships between fecundity and body parameters (fish length and body weight) were worked out and it was observed that the curvilinear relationship was the best representative and exhibited better correlations. The relationships revealed significant positive correlations, and best represented for both by the following equations:

$$F = 3.66 L^{2.0}, (r^2 = 0.710).$$

$$F = 72.42 W^{0.6}, (r^2 = 0.726).$$

3.5 Food habit

Figure (7) shows monthly fluctuations in the feeding and vacuity indices of *O. aureus* in the River. Out of the 543 specimens of the species examined, 259 (47.7%) has food in their stomachs. The feeding index of *O. aureus* ranged from 6.1% in August to 67.0% in March. The highest percentage of empty stomachs for the species was recorded during summer. The vacuity index of the species fluctuated from 16.7% in September to 85.0% in August.

Monthly differences in index of relative importance (IRI) of *O. aureus* for food items that represented more than 5% relative importance were considered to be major food items in the diet of the species is shown in Figure 8. The diet of *O. aureus* was constituted from five groups: detritus, algae, diatoms, macrophytes, and crustaceans. Minor food items observed in the specimens were aquatic insects, fish eggs and zooplankton. Detritus were the dominant item in the diet of *O. aureus* during eight months and the percentage contribution according to the index of relative importance (IRI) ranged from 14.9% in May to 76.5% in August. Diatoms occupied the second position, prevailing for three months and ranged from 0.5% in September to 48.1% in February. Algae came to the third position and ranged from 8.0% in August

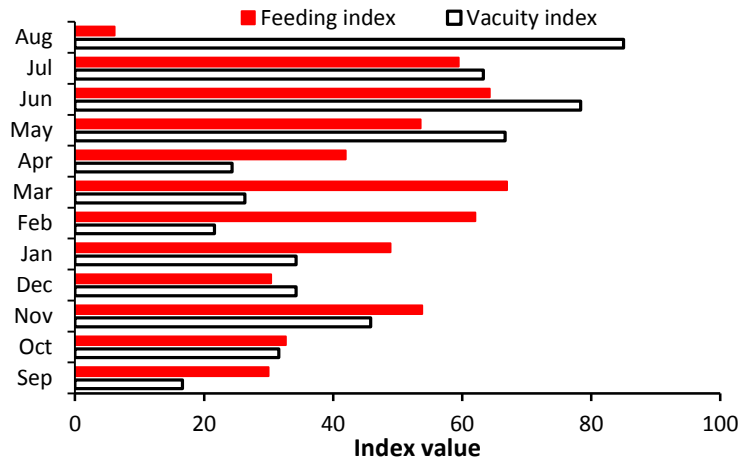


Figure 7: Monthly variations in feeding and vacuity indices of *O. aureus*

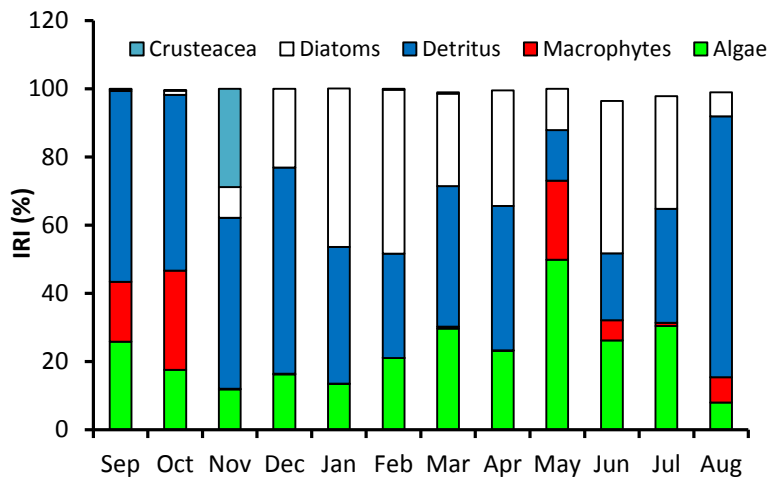


Figure 8: Monthly changes in the relative importance index (IRI%) of food items of *O. aureus*

to 49.9% in May. The contribution of crustaceans in the diet fluctuated from 0.2% in October to 28.9% in November. The overall diet composition of *O. aureus* was comprised of detritus (43.1%), diatoms (23.9%), algae (22.8%), macrophytes (7.1%) and crustaceans (6.0%).

4. DISCUSSION

The size of *O. aureus* found in the present study (6.6 to 22.9 cm) was similar those found by [22] in Wadi El-Raiyan Lakes, Egypt (8.0-23.9 cm), [24] in Rosetta branch of the Nile River, Egypt (10.5-24.5 cm), [31] in the Tigris River south of Baghdad, Iraq (3.5-27.9 cm), and [46] in the Shatt Al-Arab River, Basrah, Iraq (10-21.5 cm). However, the size of the species in the present study was lower than those reported from some other waters, such as 10.6-39.8 cm in the Benito Juárez dam, Mexico [47], 20.5-40.9 cm in El Infiernillo Reservoir, Mexico [23], and 13.9-53.8 cm in the Aguamilpa Reservoir, Mexico [25]. This may be related to differences among fishing gear used, and to different of ecological condition of these habitats.

Regardless of their sex, all *O. aureus* samples in the present study have positive allometric growth, which indicated that the fish becomes relatively stouter or deeper bodied as it increases in length [48]. This result is comparable with the finding of [22] in Wadi El-Raiyan Lakes, Egypt ($b = 3.109$). The value of b from other studied for this species revealed negative allometric growth, such as 2.77 for males, 2.73 for females and 2.87 for all individuals in the Infiernillo Reservoir, Mexico [23], 2.87 in Rosetta branch of the Nile River, Egypt [24], and 2.56 for males, 2.43 for females and 2.51 for all individuals in the Aguamilpa Reservoir, Mexico [25]. [25] stated that allometric growth is often common in species of the genus *Oreochromis*, which may be attributed mainly to problems of food, fish density, and sexual dimorphism and behaviour. Such variations in the exponent value may

depend upon various factors like number of specimens examined, stomach fullness, sex variation, disease and parasite loads, stage of maturity, condition of places of sampling, sampling season etc. [49-51].

The monthly trends in the relative condition factor (K_n) of *O. aureus* in the present study revealed that July (summer) was the most favorable time and that the population displays its worst condition in February (winter). Also, the relative condition factor of the investigated species is well-being values during October, April and July for all individuals, these may be related to the feeding activity (feed index) and the gonad development (gonado-somatic index). [25] found that the highest values of the relative condition factor (K_n) of *O. aureus* in the Aguamilpa Reservoir, Mexico occurred during September 2000 and February and May 2001, which were the months with the largest percent of spawning and post-spawning females. The fluctuations in the condition factor of many fish were observed concerning their reproductive cycle, feeding rhythms and other environmental and physiological factors [52-54].

In this study, the scales were used for age determination of *O. aureus*. The use of scales for age determination and growth studies for this species has been shown to be valid [22-24, 31]. The total length-scale radius relationship of *O. aureus* revealed a strong linear correlation. This confirms the validity of using scales for growth assessment [35]. A shorter age was reported for the *O. aureus* to be 3 years in Wadi El-Raiyan Lakes, Egypt [22], and 4 years in the Rosetta branch of the Nile River, Egypt [24]. It was also reported that *O. aureus*, attains an age of 7 years in the Tigris River south of Baghdad [31], and 8 years in the Infiernillo reservoir, Mexico [23]. This can be because of fishing pressure and sampling method.

On the other hand, the fish length of *O. aureus* in the present study at which the scales appear on the body for the first time was $a = 2.47$ cm TL. This result is comparable with the findings of [22] in Wadi El-Raiyan Lakes, Egypt ($a = 2.07$ cm TL), and [24] in the Rosetta branch of the Nile River, Egypt ($a = 2.78$ cm TL).

The theoretical growth in length (L_∞) of *O. aureus* in the present study was 27.6 cm. Similar results were obtained by [22] for the species in Wadi El-Raiyan Lakes, Egypt ($L_\infty = 27.2$ cm) and [24] in the Rosetta branch of the Nile River, Egypt ($L_\infty = 26.4$ cm). The longest values of L_∞ were 47.9 and 43.3 cm SL reported in the Infiernillo reservoir, Mexico [23], and in the Aguamilpa Reservoir, Mexico [25], respectively. [23] stated that the values of L_∞ fluctuated between 25.7 to 56.8 cm SL and K between 0.11 to 1.37 for *O. aureus* individuals that inhabiting different reservoirs in Mexico, and mentioned that the environmental differences can be more important than genetics for maturation and growth of tilapias, in additional to non-representative sampling and erroneous methodological applications.

The present growth performance index (\emptyset) of *O. aureus* was less than observed earlier for this species. [22] recorded the value of \emptyset was 2.62 for the species in Wadi El-Raiyan Lakes, Egypt. [23] stated that the values of \emptyset for *O. aureus* individuals inhabiting different reservoirs in Mexico were 2.20 to 2.97. Moreover, [24] recorded a value of $\emptyset = 2.45$ for the species in Rosetta branch of the Nile River, and 2.83 in the Aguamilpa Reservoir, Mexico [25].

Females of *O. aureus* were more abundant than males throughout the year in the present study, except in September, November, and May-July, but the overall sex ratio was 1:1.04 (male: female) and did not differ significantly of the expected ratio 1:1 ($\chi^2 = 0.02$; $P = 0.05$). Several authors have reported dominance of either males or females for *O. aureus* in some months or seasons such as; in the Lake Edku, Egypt, the overall sex ratio (males: females) was 1:1.20 [21]; in the Euphrates River at Al-Hindyah barrier, the overall sex ratio of the species (males: females) was 1.68:1 [29]; in the Tigris River, south Baghdad, the overall sex ratio of *O. aureus* (males: females) was 1.10:1, and the prevalence of males during the summer and spring, while females during autumn and winter [55]. The sex ratio of fish population changes based on spawning season, the life stage of the fish, spawning ground, fishing area, and migration [56, 57].

No fish less than 6.6 cm was caught in the present study, and this fish was female at the maturity stage, and the smallest male (9.2 cm) in the samples was sexually mature. [21] mentioned that the sizes of *O. aureus* in the Lake Edku at first sexual maturity (L_{m50}) for males and females were 8.2 and 9.2 cm, respectively. [25] stated that the length at which 50% of *O. aureus* specimens matured (L_{m50}) was 23 cm SL, and the smallest mature was 18 cm SL in the Aguamilpa Reservoir, Mexico.

The GSI indicates gonad development and maturity of fish, therefore the monthly change in GSI was followed in order to determine the time of the spawning season and reproductive behavior [32]. The GSI of the fish increases with the maturation of the fish, being maximum during the peak period of maturity and declining sharply after spawning. Two peaks of the gonado-somatic index (GSI) for *O. aureus* were showed in the present study, the highest one in April thereafter as a sign of the continuous release of eggs, and the second in September for all

individuals. This finding is in agreement with those given by [21, 55]. [21] stated that the first peak of GSI *O. aureus* in the Lake Edku, Egypt extended from February to June with a peak in GSI values of 2.17 for males and 6.27 for females in May, and the second peak extended from August to November with maximum GSI values of 1.95 for males and 3.86 for females in October. [55] found two peaks of GSI for the species in the Tigris River, south Baghdad, the highest one in May, and the second in October. [25] stated that the first four months of the year represent the peak reproductive period of *O. aureus* in the Aguamilpa Reservoir, Mexico when monthly water temperature ranged between 25 and 28.3°C. [23] mentioned that *O. aureus* have asynchronous spawning, where ovaries do not mature at the same time, but in stages, therefore, the egg liberation takes place sequentially for approximately four months that the spawning period lasts, and the species is a mouthbrooder. The mouth brooder phenomenon for *O. aureus* was clear in the present study (Fig. 9).



Figure 9: Photograph of *O. aureus* showing the mouthbrooder phenomenon

The fecundity of *O. aureus* in the present study varied from 352 to 1033 eggs when the fish ranges from 12.2 to 20.5 cm in length and 29 to 165 g in weight, this result was more or less similar to those reported in the literature about *O. aureus*. [58] stated that the fecundity of *O. aureus* ranged between 97 to 1042 eggs for fish weighted 24 to 117 g, and there was a highly significant positive correlation between fecundity and fish weight ($r=0.55$). [21] stated that *O. aureus* was markedly less fertile than *O. niloticus*, having absolute fecundity varied from 310 to 976 eggs in the fish ranging from 9-18 cm TL in Lake Edku, Egypt, while [25] found that the fecundity of *O. aureus* in the Aguamilpa Reservoir, Mexico ranged from 118 eggs (22.7cm SL) to 5,753 eggs (29cm SL). [55] mentioned that the fecundity of *O. aureus* ranged from 528 to 2,654 eggs for fish of total length ranging between 13.8 to 19.8 cm TL in the Tigris River, south Baghdad. [59] stated the species that show parental care is characterized by low fecundity and large egg size while those that do not show parental care generally have high fecundity and small egg size.

Despite the results indicated a significant correlation between fecundity of *O. aureus* with both total length and total weight, the results show that the exponent values (b) of the relationship of absolute fecundity with both body parameters were significantly different from the values suggested by [32] and thus the fecundity of *O. aureus* in the present study grows allometrically. However, [25] found no significant relationship was found between the fecundity of *O. aureus* with both fish length (SL) and body weight in the Aguamilpa Reservoir, Mexico. While, [55] found similar results for *O. aureus* in the Tigris River, south Baghdad where $b= 2.36$ with total length and $b= 0.78$ with total weight. The variation of fecundity is common across species, and within the same species because of differences in age, body length, gonadal weight and environmental factors [60, 61].

In general, the diet of *O. aureus* in the present study appears to be broadly similar to that of the species found in other locations around the world, fed mostly on plant materials originally. [19] stated that the food items of *Tilapia aureus* (*O. aureus*) in the North Carolina Reservoir contained mainly organic and inorganic detritus and large amounts of phytoplankton, and zooplankton and benthic invertebrates comprised only small percentages of the stomach contents in this reservoir. He concluded that this species is an opportunistic feeder that will successfully utilize whatever food source is available. [62] stated that *O. aureus* is an herbivorous feeding mainly on macrophytes, detritus, and microorganisms, and can shift their feeding habits depending on the abundance and composition of foods available in different aquatic environments. [63] stated that Cichlid fish species did not consume food at random but have the ability to select and choose the preferred foodstuff even during different seasons. [26] found that the species consumed macrophytes (45.2%), detritus (29.4%) and phytoplankton (16.8%) in Lake Ziway, Ethiopia. [27] also found that *O. aureus* consumed macrophytes (45.2%), algae (31.3%), detritus (14.4%) and diatoms (4.4%) in the Shatt Al-Arab River. [28] stated that *O. aureus* fed on macrophytes (49.6%), algae (25.5%), diatoms (14.5%) and detritus (6.3%) in Chybayish marsh. [55] found that *O. aureus* ingested detritus (46.3%), algae (11.8%) and macrophytes (9.3%) in Tigris River, south of Baghdad.

These results highlighted basic biological features on invasive *O. aureus* which can assist in fisheries management and conservation of the fish species in Iraqi waters.

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