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Population Dynamics and Management of Invasive Blue Tilapia (*Oreochromis aureus*) in Garmat Ali River, Basrah, Iraq

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The blue tilapia, *Oreochromis aureus* is an invasive species that has successfully established itself in most of the Iraqi waters. However, there is little information on the population dynamics of the species in these waters. Hence, the growth parameters, mortality rates, probability of capture, recruitment pattern and yield per recruit of blue tilapia in Garmat Ali River, Iraq was assessed using FiSAT II software. A total of 1664 blue tilapia fish were collected by different fishing gears from October 2019 to September 2020 for recording the relevant data. The length-weight relationship obtained was $W=0.0147*L^{3.0748}$ for fish ranging from 7.5 to 26.3 cm total length suggesting that the species shows positive allometric growth. The asymptotic length ($L\infty$), growth constant (K), theoretical age at zero-length (t_0), growth performance index (Ø') and longevity (t_{max}) were 29.9 cm, 0.205, -1.293, 2.345 and 10.7 years, respectively. The total mortality (Z), natural (M), fishing (F) and exploitation (E) were 1.09, 0.61, 0.48 and 0.43, respectively. Length at first capture (L_{50}) was found to be 13.92 cm. The main recruitment pulse was from March to July with a peak in April, which account for 18.4% of the total recruitment in the year. The relative yield per recruit analysis revealed that the present exploitation rate ($E_{present}$) for blue tilapia was below than the biological target reference points ($E_{0.1}$ and E_{max}), which denotes that this stock was not over-exploited. For management purposes, higher yields can be achieved by reducing the mesh sizes of the nets during fishing.

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1. INTRODUCTION

The blue tilapia, *Oreochromis aureus* (Steindachner, 1864) belong to the Cichlidae family which comprises of 250 genera, 2288 available species and 1728 valid species [1]. Tilapias are native to northern and western Africa, the middle east, central and south America, and India, inhabit a variety of fresh and less commonly brackish water habitats, from shallow streams and ponds through the rivers, lakes and estuaries [2]. Tilapia is the generic name of a group of cichlids endemic to Africa. The group consists of three important genera namely *Oreochromis, Sarotherodon* and *Coptodon* (*Tilapia*), each includes many species including Nile tilapia *Oreochromis niloticus,* blue tilapia *O. aureus,* mango tilapia (*Sarotherodon galilaeus*) and redbelly tilapia *Coptodon zillii* [3]. Tilapia are exotic fish to Iraqi waters and there are three species present viz., *O. niloticus, O. aureus* and *C. zilli* [4].

O. aureus is native to tropical and subtropical Africa and the Middle East and can be found in several countries. Due to its popularity as a food fish, *O. aureus* has been introduced into many other countries outside its native range for aquaculture and aquatic vegetation control. It is reared widely all over the world, and escapes or releases from aquaculture facilities, zoological parks and aquaria are common [5]. *O. aureus* can tolerate a wide range of salinity up to 20‰ and water temperature to about 8°C [6].

In Iraq, *O. aureus* was first reported from the main outfall drain at Basrah, south of Iraq by Mutlak and Al-Faisal [7]. The species is now well established and has become dominant in several Iraqi waters [4,8-12].

The growth, mortality and yield-per-recruit of *O. aureus* have been evaluated by researchers in different natural water bodies the world over using FiSAT II (FAO-ICLARM Stock Assessment Tools) software such as [13] in El-Raiyan Lakes, Egypt; [14] in the Infiernillo reservoir, Mexico, and [15] in the Aguamilpa Reservoir, Mexico. However, some authors used scales for determining age and growth, and also reported mortality and yield-per-recruit of *O. aureus* such as [16] in Rosetta branch of the Nile River, Egypt and [17] in Nozha Hydrodrome, Egypt. Recently, the population dynamics and management of *O. aureus* in Shatt Al-Arab River, Iraq has been reported by Mohamed and Abood [18], and the present study is a continuation of investigation on this species in Iraq.

This study evaluates the growth parameters, mortality rates, probability of capture, recruitment pattern and yield per recruit of *O. aureus* population in Garmat Ali river, north of Basrah, to provide basis for stock assessment as well as information for proper management of this cichlid species.

2. MATERIALS AND METHODS

The Garmat Ali River is a waterway between the east Hammar marsh and Shatt Al-Arab River, situated in the north of Basrah city within the geographical coordinates 30°34ˉ to 30°35ˉ N and 47°43ˉ to 47°46ˉ E (Fig. 1). Its length is about 6 km with a width of 280 m and the mean depth of 9 m. This river is a navigable river with noticeable boats and fishery activities and considered as a source of irrigation for the adjoining areas. The river is affected by the tidal current of the Arabian Gulf through the Shatt Al-Arab River. The salinity of the river ranged from 1.2 ‰ in January to 9.9 ‰ in September.

Fish samples of blue tilapia were collected from two sites on the river, one located near Al-Najeebia Bridge opposite the Naval Academy and another in the upper river area before its confluence with the East Hammar marsh. Fish were caught using gill nets of varying mesh size (200 m length with 15 to 35 mm mesh size), cast net (9 m diameter, with 15x15 mm, mesh size) and electro-fishing by generator engine (providing 300-400V and 10A) from October 2019 to September 2020. The samples were immediately preserved in ice and transported to the laboratory for subsequent analysis.

The total length of each fish was measured to the nearest 1.0 mm. The data were then pooled monthly from the two stations and grouped into 1.0 cm class interval, sequentially arranged according to a time series of 12 months, and stored in FiSAT II package [19] for subsequent analysis. The total length (L) relationship to the weight (W) was established using the equation [20]: $W = a \times L^b$, where a is the intercept and b is the slope (growth coefficient). To test the b value against the value of 3, the Student's t-test was deployed to predict the type of growth [21]. The length-weight relationship was established on

Fig. 1. Map of Garmat Ali river with locations of study sites

Microsoft Excel version 10. For comparison with other studies, the standard length (SL) was converted to total length (TL) using the following equation [22]: TL= (0.57+ SL)/0.76.

The fitting of the best growth curve was based on the ELEFAN I routine of the FiSAT II software (FAO-ICLARM Stock Assessment Tools) after Gayanilo et al. [19], (2005), which allows the curve to be fitted through the maximum number of peaks of the length-frequency distribution. With the help of the goodness of fit value (R_n), growth constant (K) and asymptotic length ($L\infty$) were estimated [23, 24]. The theoretical age at zero-length (t_0) was calculated using the empirical equation of Pauly [23]:

$$\log_{10}(-t_0) = -0.3922 - 0.275 \log_{10}L\infty - 1.0381 \log_{10}K$$

The growth performance index (Ø′) was computed as [25]:

$$Ø' = \log_{10}K + 2 \log_{10}L\infty$$

Longevity (t_{max}) was obtained as [23]:

$$t_{max} = t_o + 3/K.$$

The total mortality rate (*Z*) was estimated using length-converted catch curve analysis method of Pauly [23] in FiSAT II program using the input parameters $L\infty$ and K, and selecting the best points on the straight line of the right arm of the curve. Estimation of natural mortality rate (M) was obtained by Pauly's empirical equation [26] as the mean annual water temperature of the river waters (T= 26.3°C):

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L\infty + 0.6543 \log_{10} K + 0.463\log_{10} T$$

The fishing mortality rate (F) was calculated from the relation F= (Z-M). The exploitation rate (E) was calculated as E= F/Z [27]. The histogram showing probability of capture for each size class was obtained by backward extrapolation of the straight portion of the descending part of the catch curve, a method incorporated into the FiSAT software package. The inbuilt logits method was used to derive values of the lengths at capture at probabilities of 0.25 (L_{25}), 0.5 (L_{50}) and 0.75 (L_{75}).

The pattern of recruitment during the year was analyzed from the length frequency data. Growth parameters ($L\infty$ and K) were used as inputs to estimate the month-wise recruitment pattern [28] as described in FiSAT software package.

The relative yield-per-recruit (Y'/R) analysis was carried out using the knife-edge analysis of Beverton and Holt [29] as modified by Pauly and Soriano [30], and the data of $L_c/L\infty$ and M/K values as described in FiSAT software package to estimate the biological target reference points, $E_{0.1}$ and E_{max} [31].

3. RESULTS

3.1 Growth Parameters

A total of 1664 blue tilapia fishes were examined. The total length ranged from 7.5 to 26.3 cm (Fig. 2). The most frequent length groups of the species were 8.0-11.0 cm and 14.0–17.0 cm which constituted 24.8 and 54.4%, respectively. The dominant individuals that ranged from 13 to 17 cm formed 62.0% of the total catch.

The total weight ranged between 6 and 356 g and when considered along with the total length of 1622 fishes gave the following equation (Fig. 3):

$$W=0.0147*L^{3.0748}, r^2= 0.963.$$

The t-test revealed that the regression was significantly different from 3 (t= 4.97, P<0.05), indicating positive allometric growth.

Using the ELEFAN I analysis in FiSAT II software, the optimized von Bertalanffy's growth curve yielded the following growth estimates with the K-scan (Fig. 4): L_∞= 29.9 cm and K= 0.25, while the estimated value of goodness of fit of model estimation R_n= 0.204.

The curve superimposed over the restructured length-frequency histogram is presented in Fig. 5. The estimated t_o value for blue tilapia was -1.293 years. The estimated growth performance index (Ø) was 2.345 (Table 1). The results indicated that the maximum life span of blue tilapia in Iraqi waters was 10.7 year.

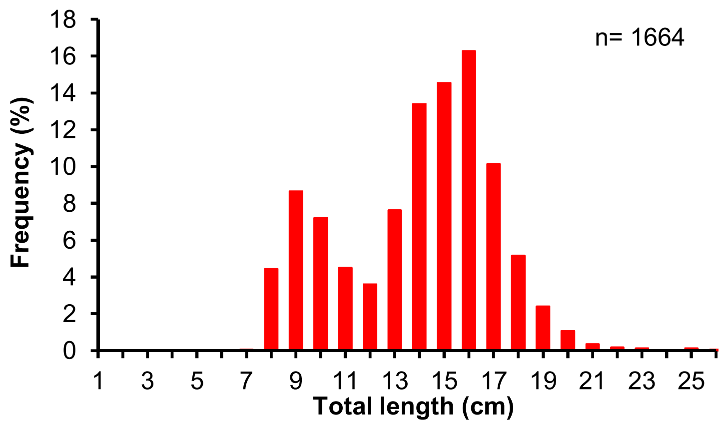

Fig. 2. The overall length-frequency distribution

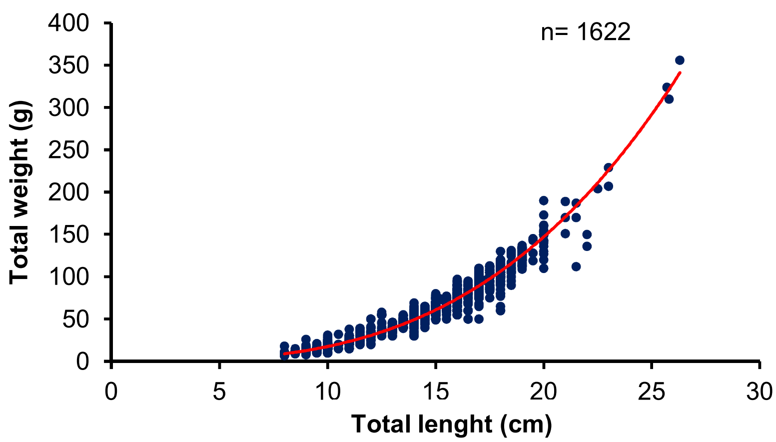

Fig 3. The length-weight relationship

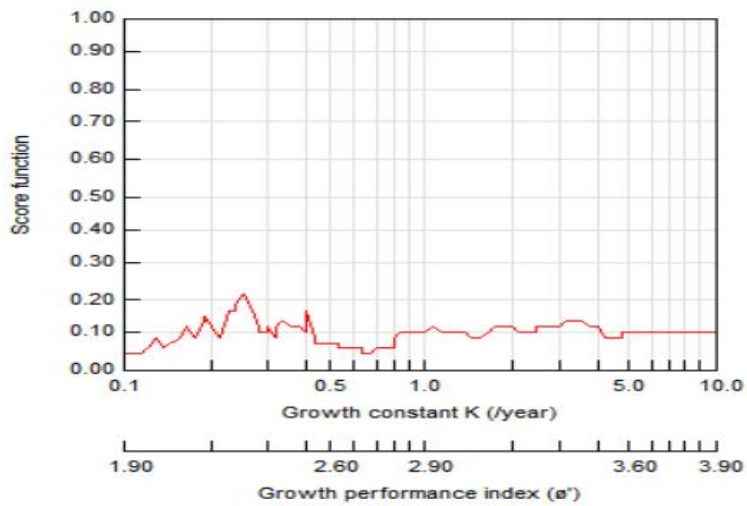

Fig. 4. K-scan routines

Table 1. Comparison of population parameters of *O. aureus* in different locations

Author	Method	L∞	K	t_o	Ǿ	L_c	Z	M	F	E	Location
Mehanna [13]	Scales	27.2	0.56	-0.32	2.62	15.3	1.69	0.25	1.44	0.85	El- Raiyan Lakes, Egypt
Mahmoud and Mazrouh [16]	Scales	26.4	0.40	-0.21	2.45	10.5	2.13	0.83	1.30	0.61	Rosetta branch, Nile River, Egypt
Messina et al. [15]	FiSAT	43.3 SL	0.36	-0.41	2.83		1.94	0.83	1.10	0.57	Aguamilpa Reservoir, Mexico.
Mahmoud et al. [17]	Scales	38.1	0.21	-0.25	2.48	13.2	0.85	0.51	0.34	0.40	Nozha Hydrodrome, Egypt.
Mohamed and Abood [18] (2020)	FiSAT	27.8	0.49	-0.27	2.58	13.3	2.49	1.08	1.41	0.57	Shatt Al-Arab River, Iraq.
Values from our study	FiSAT	29.9	0.25	-1.29	2.35	13.9	1.09	0.61	0.48	0.43	Garmat Ali river.

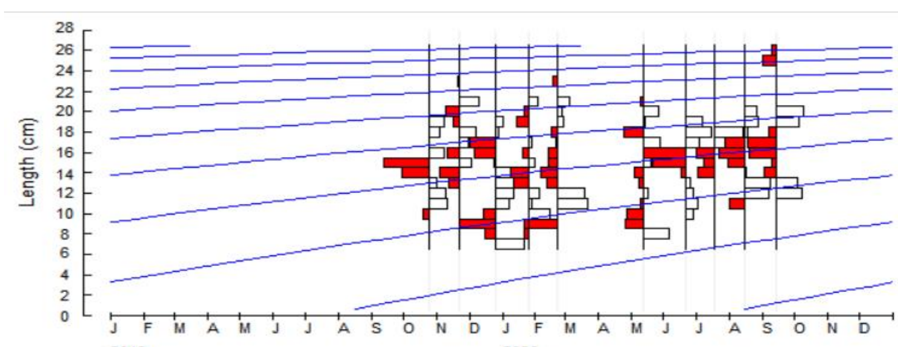

Fig. 5. Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1

3.2 Mortality and Exploitation Rates

The estimated rate of total mortality (Z) applying the length-converted catch curve analysis method was 1.09 (Fig. 6), and the natural mortality rate (M) was 0.611, while the rate of fishing mortality (F) was 0.479. Hence, the exploitation rate (E) was 0.43.

3.3 Probability of Capture

Based on the length converted catch curve values, the probability of capture was analyzed and is presented in Fig. 7. The values of L_{25}, L_{50} and L_{75} were found to be 12.48, 13.92 and 15.37 cm, respectively. Hence, fish appeared to be recruited to the fishery at a mean size of L_{50}= 13.92 cm.

3.4 Recruitment

The recruitment pattern was continuous throughout the year (Fig. 8), but the main recruitment pulse was from March to July with a peak in April, which accounts for 18.4% of total recruitment in the year.

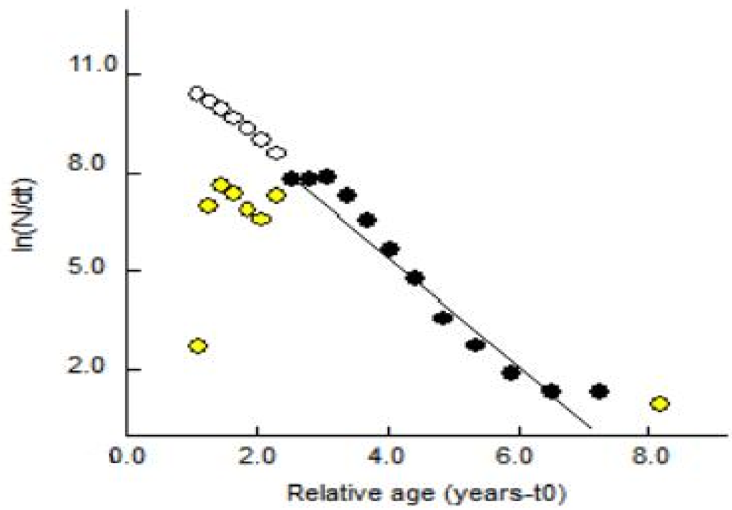

Fig. 6. Length converted catch curves

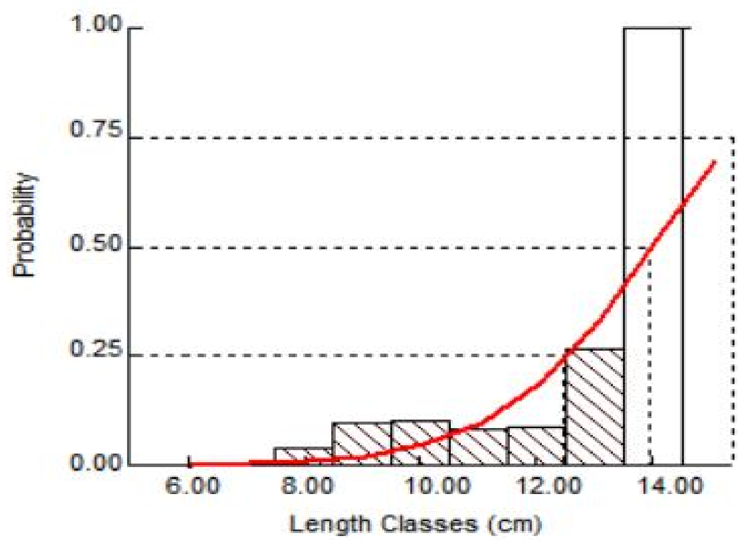

Fig. 7. Probability of capture

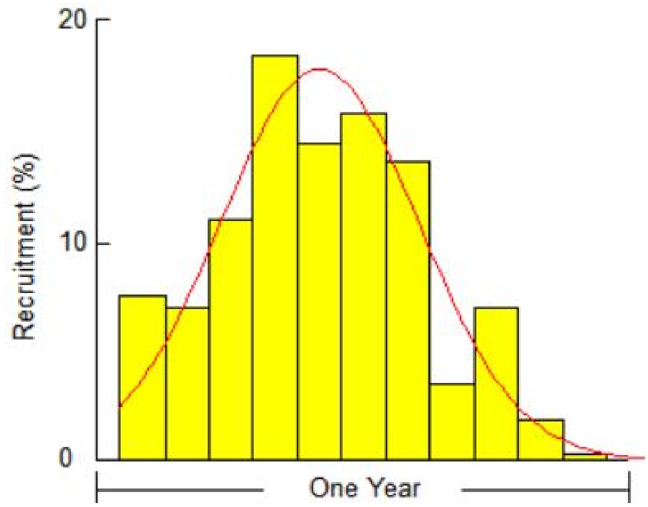

Fig. 8. Recruitment pattern

3.5 Yield Per Recruit (Y'/R) and Biomass Per Recruit (B'/R)

The relative yield per recruit (Y´/R) of blue tilapia was analyzed using the knife-edge selection in Beverton and Holt Y/R analysis incorporated in FiSAT II (Fig. 9) with the functions of M/K and L/L∞ which were 2.80 and 0.466 respectively. The estimate values of $E_{0.1}$, $E_{0.5}$ and E_{max} were 0.706, 0.365 and 0.877, respectively. The present exploitation rate ($E_{present}$) was below the biological target reference points ($E_{0.1}$ and E_{max}) indicating the stock of was under a state of exploitation. The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were 0.017 and 0.151, respectively.

4. DISCUSSION

The assessment of fish populations is essential to address one of the main objectives of fishery science, which is maximizing yield, while safeguarding the long-term viability of populations and ecosystem [32].

The sizes of blue tilapia in the current study ranged from 7.5 to 26.3 cm which was wider than those obtained for this species by other authors in different geographic localities such as [13] in El-Raiyan Lakes, Egypt (8.0-23.9 cm), [16] in Rosetta branch of the Nile River, Egypt (10.5-24.5 cm), [33] in the Shatt Al-Arab River, Iraq (10-21.5 cm) and [11] in the Garmat Ali River (6.6-22.9 cm). Conversely, the sizes of the species in the present study were smaller than those reported from other waters, such as 20.5-40.9 cm in El Infiernillo Reservoir, Mexico [14], 13.9-53.8 cm in the Aguamilpa Reservoir, Mexico [15] and 12.5-31.5 cm in the Nozha Hydrodrome, Egypt [17]. The differences in sizes of the fish across different geographic regions may partly be attributed to various factors including water condition, restricted habitats, food availability, population density, levels of intraspecific competition, fishing pressure and fishing gears [34-36].

In the present study, the value of the growth coefficient (b) of length-weight relationship was found to exhibit positive allometric growth. Riedel et al. [36] stated that this type of growth implies that the fish becomes relatively stouter or deeper-bodied as it increases in length. Our results are in agreement with those reported by Mehanna [13] in El-Raiyan Lakes, Egypt. On the other hand, some workers reported negative allometric growth (2.870 in the Infiernillo Reservoir, Mexico [14], 2.872 in Rosetta branch of the Nile River, Egypt [16], 2.510 in the Aguamilpa Reservoir, Mexico [15] and 2.973 in the Nozha Hydrodrome, Egypt [17]). The variations in b value may possibly be due to factors like sizes of fish examined, stomach fullness, sex, diseases, maturity, environment and season [20,21,37].

The growth parameters obtained in this study and those reported from different geographic locations which were obtained by applying FiSAT II software and scales analysis are presented in Table 1. The asymptotic length (L∞) in this study was higher than those recorded for this species in El-Raiyan Lakes, Egypt [13], Rosetta branch, Nile River, Egypt [16] and Shatt Al-Arab River, Iraq [18], whereas these were lower than those found in Aguamilpa Reservoir, Mexico [15] and Nozha Hydrodrome, Egypt [17]. The value of K was within the range observed in other populations of *O. aureus*, where the lowest value (0.21) was documented by Mahmoud et al. [17] from the Nozha Hydrodrome, Egypt, and the highest one was 0.56 reported by Mehanna [13] from the El-Raiyan Lakes, Egypt. The study showed that the t_o and Ǿ values in this study were the highest for t_o and the lowest for Ǿ, compared to other studies (Table 1). It was also found that the length at first capture (L_c) was 15.5 cm which was well within the range reported for this species in other studies. The value of t_{max} was found to be 10.7 years in our study. The t_{max} was reported to be 7.5 years in the fish from Rosetta branch, Nile River, Egypt [16], 8.0 years in the Aguamilpa Reservoir, Mexico [15] and 14.5 years in the Nozha Hydrodrome, Egypt [17]. These differences in the growth of this species in different locations could be attributed to several factors viz., environmental differences, habitat, availability of food, metabolic activity, reproductive activity, the genetic constitution of the individual, fishing pressure, non-representative sampling and erroneous methodological applications [34,24,14,38].

A comparison was made between the values of the total mortality (Z), natural mortality (M), fishing mortality (F) rates and the exploitation rate (E) of blue tilapia with those reported by the various authors in different regions (Table 1). The values of Z, M and F obtained were within the ranges of these parameters observed in other populations of the species. The value of the present exploitation rate ($E_{present}$) was 0.43, and the lowest value of E for the species was 0.40 recorded by Mahmoud et al. [17] from the Nozha Hydrodrome, Egypt, while the highest value was 0.85 obtained by Mehanna [13] from the El-Raiyan Lakes, Egypt. According to Gulland [27] the optimum exploitation rate is 0.5, hence, the exploitation rate of this species in the present study indicates that the species is under exploitation.

The recruitment pattern was continuous throughout the year, but the main recruitment pulse was from March to July with a peak in April. There is no report as yet on the recruitment of *O. aureus* for comparison purposes. However, the highest peak of the gonado-somatic index (GSI) of this species in the Garmat Ali River was in April and the second peak in September [11]. Messina et al. [15] reported that the highest frequency of spawning in *O. aureus* occurred from January to May when monthly water temperature ranged between 25 and 28.3°C. Spawning in blue tilapia is partially asynchronous in that, the gonads do not fully mature at the same time [14].

The results of the relative yield-per-recruit (Y'/R) analysis indicated that the present exploitation rate ($E_{present}$= 0.43) was considerably lower than the optimum exploitation rate ($E_{0.1}$= 0.706 and the maximum rate (E_{max}= 0.877) which indicates that the stock was not over exploited. Mahmoud and Mazrouh [16] reported that the fishing mortality in *O. aureus* was very close to the maximum sustainable yield per recruit and the optimum fishing mortality of the species. This means that the present level of exploitation rate was optimum in the Rosetta branch, Nile River, Egypt. Mahmoud et al. [17] found that the exploitation rate of blue tilapia in Nozha Hydrodrome, Egypt did not reach the target reference points. Mohamed and Abood [18]

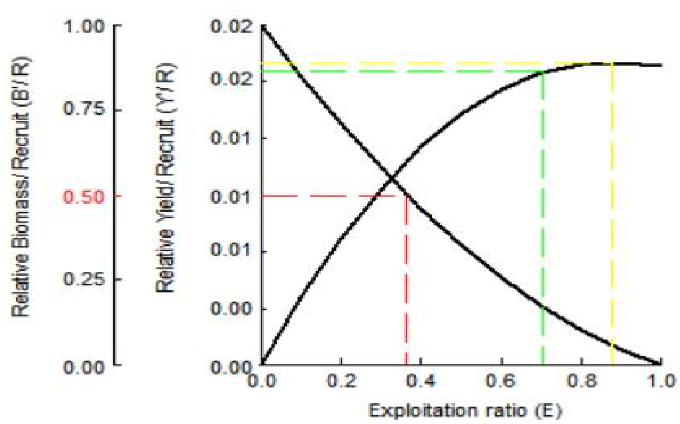

Fig. 9. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses

reported that the exploitation rate for Blue tilapia in the Shatt Al-Arab river was way below the biological target reference points ($F_{0.1}$ and F_{max}), indicating that the species was not overexploited. Conversely, Mehanna [13] noted that the exploitation rate of blue tilapia was higher than the target reference points for the species in Wadi El-Raiyan Lakes, Egypt. Also, Messina et al. [15] reported that the fishery of *O. aureus* in the Aguamilpa Reservoir, Mexico showed signs of overfishing, where the exploitation rate of the species was 0.57/year, higher than the optimal level proposed by Gulland [27].

5. CONCLUSION

The study revealed that the *O. aureus* stock in Iraqi waters was underexploited. Also, there was a large difference between the length at first capture (L_c= 13.9 cm) and the length at first maturity (L_m), compared to the report of Al-Wan [39] who stated that the length at first maturity (L_m) of blue tilapia in Garmat Ali river ranged from 6.6 to 9.2 cm. Consequently, more yields could be obtained through a reasonable decrease in the size of the first capture without necessarily leading to overexploitation. This can be achieved by reducing the mesh sizes of the nets for fishing this species. The results from our study could be used by policy makers in fishery management to sustain the population of blue tilapia in Iraqi waters and ensure that this species is not overexploited due to fishing.

ETHICAL APPROVAL

As per international standard written ethical permission has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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