

Population dynamics and management of two cichlid species in the Shatt Al-Arab River, Iraq

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Abstract

Cichlids are invasive fish to Iraqi waters and became well established and prevailing in different waters. Despite that, there is no stock assessment study conducted for these fish. So, growth, mortality, recruitment and yield-per-recruit of two cichlid's species; *Coptodon zillii* and *Oreochromis aureus* from the Shatt Al-Arab River, Iraq were evaluated from November 2015 to October 2016 using the FiSAT software. A total of 1285 *C. zillii* (2.9-24.0 cm TL) and 1353 *O. aureus* (4.5-25.0 cm TL) were examined. Length-weight relationships were derived, indicating allometric growth for both species. The growth parameters (L_{∞} , K , R_n , t_0 and \emptyset) obtained for *C. zillii* were 25.5 cm, 0.320, 0.212, -0.793 and 2.318, respectively, while for *O. aureus* were 27.8, 0.490, 0.214, -0.271 and 2.578, respectively. The annual rate of total mortality (Z), fishing (F) and natural (M) for *C. zillii* was found to be 1.51, 0.84 and 0.68 respectively, and for *O. aureus* 2.49, 1.08 and 1.41, respectively. The present exploitation rates (E_{present}) for *C. zillii* and *O. aureus* were computed to be 0.454 and 0.57, respectively. Lengths at first capture (L_c) were 12.97 cm for *C. zillii* and 13.25 cm for *O. aureus*. The peaks of recruitment of *C. zillii* and *O. aureus* were from February to May and May to July, respectively. The E_{present} for *C. zillii* and *O. aureus* were below the biological target reference points ($F_{0.1}$ and F_{max}), indicating that these species were not overexploited. For management purposes, more yields could be obtained by an increase in the fishing activities on cichlids.

Keywords: Cichlids, Growth, Mortality, Shatt Al-Arab River, Yield-per-recruit

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INTRODUCTION

The family Cichlidae plays an important role in commercial fisheries and aquaculture worldwide. The total landing of cichlids fish in the world was about 1.6 million tons in 2016 (FAO, 2018), and it was the second most important fish in fish farming in the world after carps, with a production of 6.3 million tons in 2018 (FAO, 2019). There are three major taxonomic groups of tilapia, namely *Oreochromis*, *Sarotherodon* and *Coptodon* (*Tilapia*), each includes many species including Nile tilapia *Oreochromis niloticus*, blue tilapia *O. aureus*, gillean tilapia (*Sarotherodon galilaeus*) and redbelly tilapia *Coptodon zillii* (McAndrews, 2000). Tilapias are native to Africa and the southwestern Middle East, inhabit a variety of fresh and less commonly brackish water habitats, from shallow streams and ponds through the rivers, lakes and estuaries (Uneke, 2015).

C. zillii and *O. aureus* are widely introduced into different waters all over the world as a food fish or as a control of aquatic vegetation. *C. zillii* can tol-

erate a wide range of salinity at 10 to 30‰ (El-Sayed, 2006), while *O. aureus* at up to 20‰ (Popma and Masser, 1999). 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 (Popma and Masser, 1999). Several authors have studied the growth, mortality and management of *C. zillii* and *O. aureus* populations in different water bodies in the world using FiSAT II (FAO-ICLARM Stock Assessment Tools) software (Mehanna, 2004; Jiménez-Badillo, 2006; Mahmoud and Mazrouh, 2008; Messina *et al.*, 2010; Abdul and Omoniyi, 2011; Mahomoud *et al.*, 2011; Mahmoud *et al.*, 2013; El-Bokhty and El-Far, 2014; Uneke and Nwani, 2014). Tilapia species are invasive fish to Iraqi waters in ways that are not known, and early records show that *C. zillii* was caught from the Euphrates River near Musaiib City, Centre of Iraq (Saleh, 2007). Now, three tilapia species, *O. aureus*, *C. zillii* and *O. niloticus* are well established and dominating in different water bodies of Iraqi. The cichlid's species constituted 21.3% of fish assemblage in the

Shatt Al-Arab River during 2015-2016 (Mohamed and Abood, 2017) and 32.3% of fish assemblage in the same river at Abu Al-Khasib district during 2018-2019 (Mohamed and Hameed, 2019). However, there is no stock assessment study conducted on these invasive species in Iraqi waters. Therefore, the present work covers growth parameters, mortality rates, probability of capture, recruitment pattern and yield per recruit of the *C. zillii* and *O. aureus* populations in the Shatt Al-Arab River, to evaluate the population parameters required for proposing future plans for managing the tilapia stocks in Iraqi waters.

MATERIALS AND METHODS

Fish sampling: The materials for this study were obtained from three sites on the Shatt Al-Arab River, near Al-Dair Bridge, Abu Al-Khasib district and north Fao town (Fig. 1) from November 2015 to October 2016. The fish was caught using gill nets, cast net and electro-fishing (Mohamed and Abood, 2017).

Growth : The length-frequency data were pooled into a bimonthly period from different stations and subsequently grouped into 1.0 cm class intervals for analysis. The total length (L) and weight (W) were measured for each species to the nearest 1 mm and 0.1 g, respectively. The length-weight relationship was estimated for both species by using formula (Le Cren, 1951): $W = a L^b$, a and b are constants. The hypothesis of isometric growth (Ricker, 1975) was tested with Student's t-test by using Microsoft Office Excel 2010.

The fitting of the best growth curve was based on the ELEFAN I module implemented in the FAO-ICLARM Fish Stock Assessment Tools (FiSAT II, ver. 1.2.2.) software (Gayaniilo *et al.* 2005), which allows the fitted curve through the maximum number of peaks of the length-frequency distribution where we find the highest R_n value. The estimate of theoretical age at length zero (t_0) was obtained by using the empirical equation of Pauly (1983): $\log_{10}(-t_0) = -0.3922 - 0.275 \log_{10}L_{\infty} - 1.0381 \log_{10}K$ Eq.1

Growth performance index (ϕ') for each species was computed based on the length data using the following equation (Pauly and Munro, 1984): $\phi' = \log_{10}K + 2 \log_{10}L_{\infty}$ Eq.2

Mortality rates: The instantaneous rate of total mortality (Z) estimated using the length converted catch curve method incorporated in FiSAT package by fitting a regression line through the natural logarithm of the number of fish in various length groups against their relative age. The natural mortality rate (M) was calculated from Pauly's (1980) empirical formula with an input water temperature (T) of 24.6 °C (Mohamed and Abood, 2017): $\log_{10} M = -0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K + 0.463 \log_{10} T$ Eq.3

The fishing mortality (F) for each species was

computed as $F = Z - M$ and the current exploitation rate was computed from the rate F/Z (Gulland, 1971).

The probability of capture for each species was calculated by backward extrapolation of the right descending limb of the length converted catch curve using L_{∞} and K parameters as an input in FiSAT. A selectivity curve was generated using linear regression fitted to the ascending data points from a plot of the probability of capture against length, which 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}).

Recruitment pattern: Recruitment patterns for each species were obtained by backward projection on the length axis of a set of length-frequency data, and using the growth parameters L_{∞} and K as described in the FiSAT routine. The peaks and troughs of the graph obtained reflect the seasonality of recruitment.

Yield per recruit (Y'/R) and biomass per recruit (B'/R): The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were estimated for each species by using the knife-edge analysis of Beverton and Holt (1966) as modified by Pauly and Soriano (1986). The calculations were done using the FiSAT software package. The data of L_c/L_{∞} and M/K values were used to estimate E_{max} (the exploitation rate giving maximum sustainable yield per recruit), $E_{0.1}$ (the exploitation rate at which the marginal increase in relative yield-per-recruit is 10% of its value at $E = 0$, the optimum fishing mortality), and $E_{0.5}$ (the exploitation rate corresponding to 50% of the unexploited relative biomass per recruit (B'/R)), were estimated. The values of the current exploitation rates and the biological target reference points ($F_{0.1}$ and F_{max}) were used to assess the status of *C. zillii* and *O.*

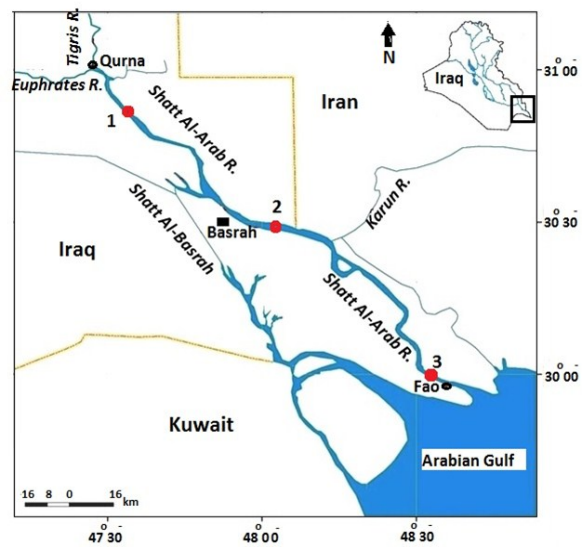


Fig. 1. Map of Shatt Al-Arab with locations of study sites (sketched by the author).

aureus fisheries in this study (Cadima, 2003).

RESULTS

Growth parameters: The monthly samples of each species were pooled to produce a single length-frequency distribution to determine the dominant size groups and their percentage composition (Fig. 2). A total of 2638 fish specimens (distributed as 1285 *C. zillii* and 1353 *O. aureus*) were involved in this study. The length of fish ranged from 2.9 to 24.0 cm and their total weight varied between 0.5 and 275.8 g. Fish lengths 11-16 cm formed 70.7% of the species caught. The total length of *O. aureus* varied from 4.5 to 25.0 cm while their total weight ranged between 1.9 and 311.8 g, with fish of 13-16 cm dominating the catch forming 62.5% of the species caught.

The length-weight relationships for both species were (Fig. 3):

$$W = 0.013L^{3.159}, \quad n = 852, \quad 2.9-24.0 \text{ cm}, \quad r^2 = 0.977 \text{ for } C. \text{ zillii}$$

$$W = 0.015L^{3.058}, \quad n = 1082, \quad 4.5-25.0 \text{ cm}, \quad r^2 = 0.929 \text{ for } O. \text{ aureus.}$$

In terms of growth type, both species showed positive allometric growth ($t = 9.56$ and 2.24 , $P < 0.05$). The asymptotic length (L_∞) and growth coefficient

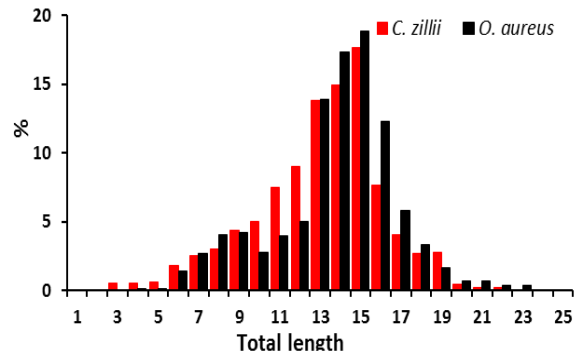


Fig. 2. Overall length frequencies of *C. zillii* and *O. aureus*.

(K) of for both species from K-scan routine (Fig. 4) were observed by using the direct fit of length-frequency data in ELEFAN I and the response surface (R_n) for the von Bertalanffy growth curve (Fig. 5). Therefore, the L_∞ , K and R_n obtained for *C. zillii* were 25.5 cm, 0.320 year^{-1} and 0.212, respectively. The t_0 was estimated as -0.793 years, and the growth performance index (ϕ') was 2.318. The L_∞ , K, R_n , t_0 and ϕ' obtained for *O. aureus* were 27.8, 0.490, 0.214, -0.271 and 2.578, respectively. The VBGF for both species could thus

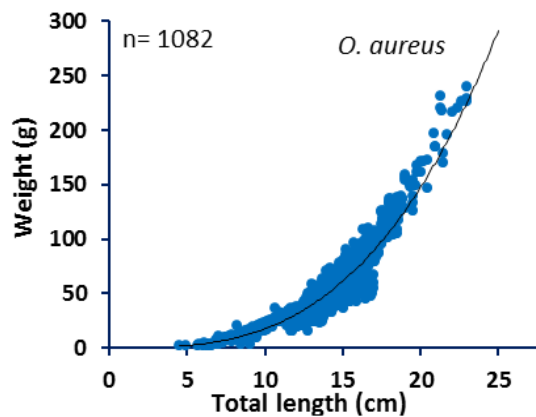
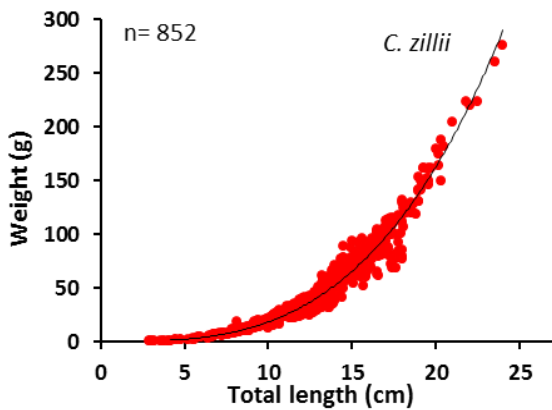


Fig 3. Length-weight relationships of *C. zillii* and *O. aureus*.

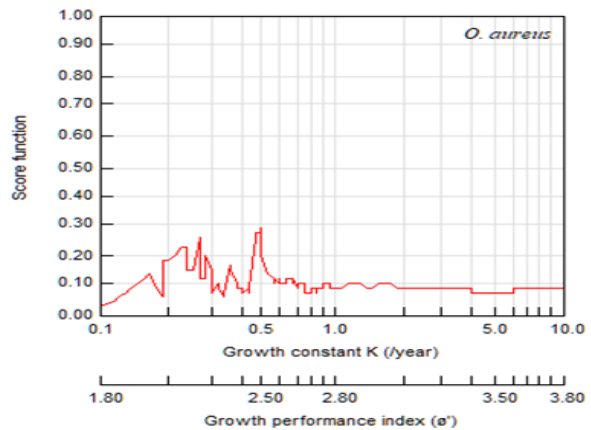
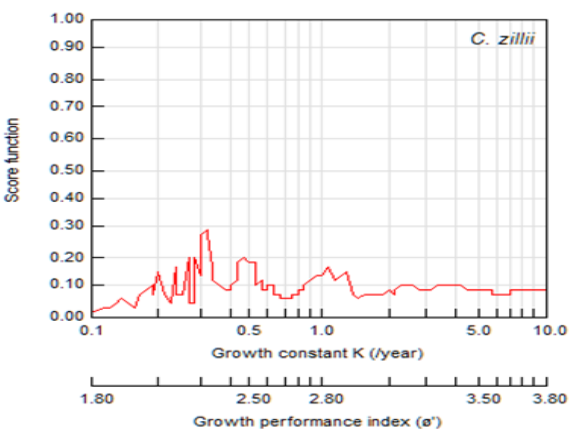


Fig. 4. K-scan routines of *C. zillii* and *O. aureus*.

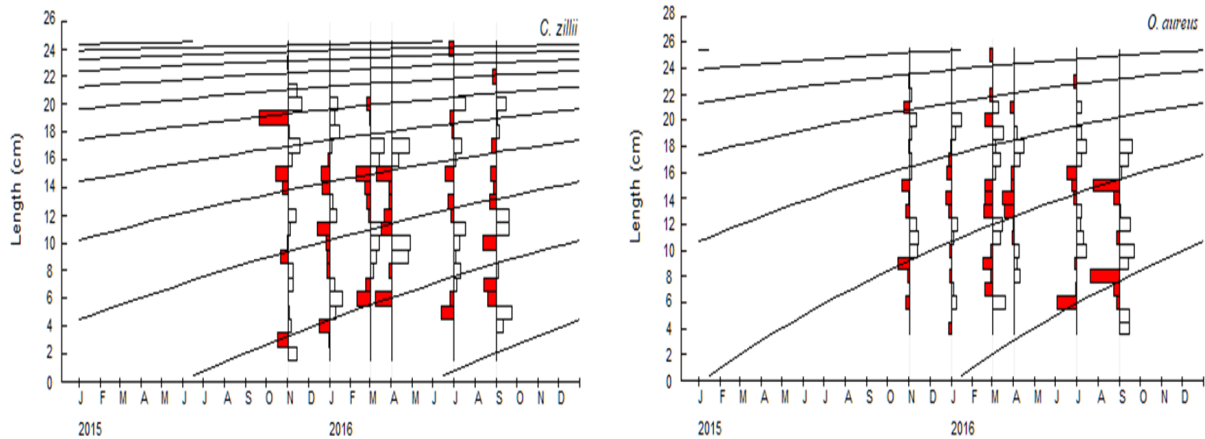


Fig. 5. Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *C. zillii* and *O. aureus*.

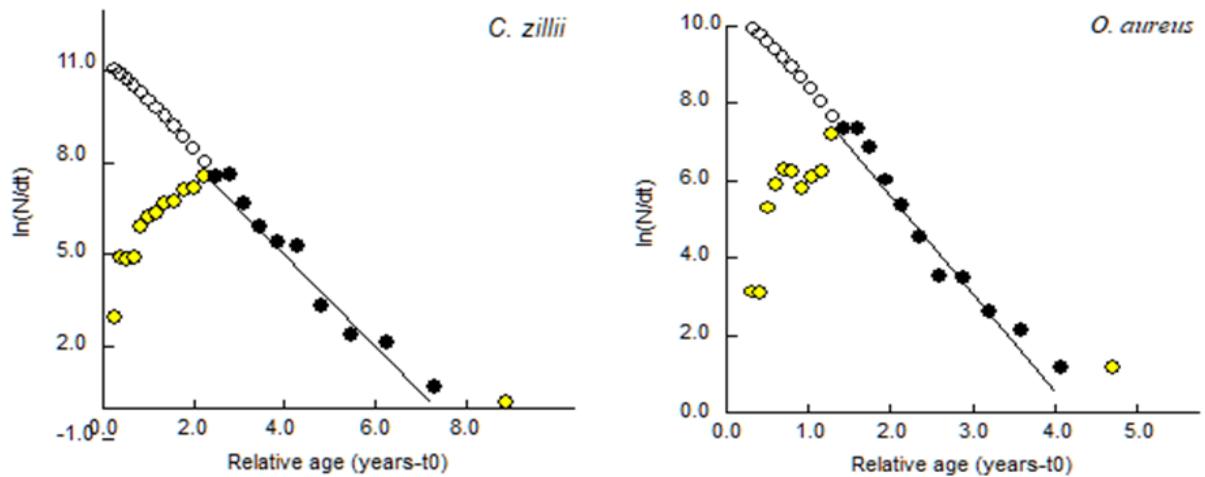


Fig. 6. Length converted catch curves of *C. zillii* and *O. aureus*.

be written as:

$$L_t = 25.5 (1 - e^{-0.32(t + 0.793)}) \text{ for } C. zillii$$

$$L_t = 27.8 (1 - e^{-0.49(t + 0.271)}) \text{ for } O. aureus$$

Mortality and exploitation : Length-converted catch curves of the two species are shown in Fig. 6. The coefficient of determination (r^2) ranged from 0.967 in *C. zillii* to 0.964 in *O. aureus*. The annual instantaneous rates of total mortality (Z) for *C. zillii* was 1.51 and for *O. aureus* 2.49 per year. The value of the instantaneous natural mortality coefficient (M) for *C. zillii* was 0.84 and for *O. aureus* was 1.08. From these results, the fishing mortality coefficient (F) and the present exploitation rate (E_{present}) for *C. zillii* were computed to be 0.68 and 0.454, respectively, and for *O. aureus* 1.41 and 0.57, respectively.

Probability of capture: Based on the length converted catch curve values, the probability of capture of both species were then analyzed and presented in Fig. 7. The values of L_{25} , L_{50} and L_{75} for *C. zillii* were found to be 11.32, 12.97 and 14.62 cm, respectively, and for *O. aureus* were 11.65, 13.25 and 14.84 cm, respectively. Therefore, the length at the first capture " L_c " values were 12.97

cm for *C. zillii* and 13.25 cm for *O. aureus*.

Recruitment: The recruitment pattern of *C. zillii* was recruited in the fishery from January to July, but exhibited peak between February-May, which account to 63.9% of the recruits, whereas the recruitment pattern of *O. aureus* was continuous throughout the year, but showed peak between May to July, which constituted 40.5% of total recruitment throughout the year (Fig. 8).

Yield per recruit (Y'/R) and biomass per recruit (B'/R): The relative yield and biomass per recruit analyses for both species were conducted using growth and mortality parameters and selectivity derived from the probability of capture data (Fig. 9), indicated that the maximum (Y'/R) was obtained at $E_{\text{max}} = 0.938$ for *C. zillii* and $E_{\text{max}} = 0.791$ for *O. aureus*. The $E_{0.1}$ and $E_{0.5}$ estimates were 0.751 and 0.376 for *C. zillii*, respectively, whereas 0.668 and 0.361 for *O. aureus*, respectively.

DISCUSSION

The results revealed that the length-weight relationships for *C. zillii* and *O. aureus* showed positive allometric pattern. In general, Riedel *et al.*

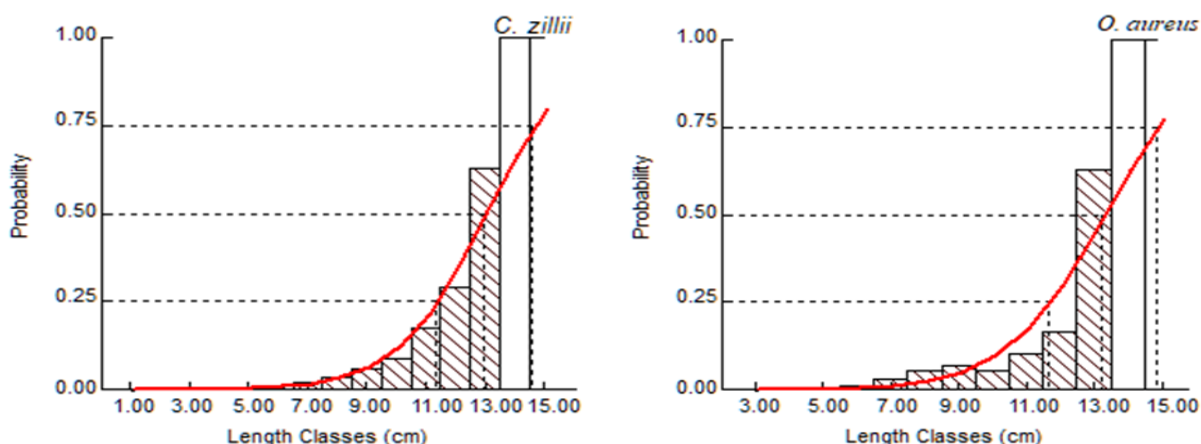


Fig. 7. Probability of capture for *C. zillii* and *O. aureus*.

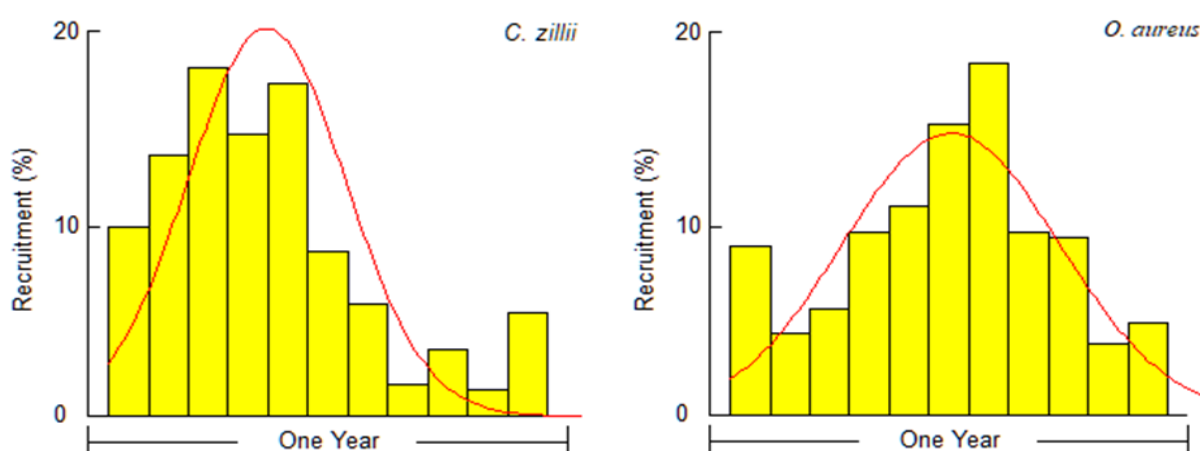


Fig. 8. Recruitment patterns of *C. zillii* and *O. aureus*.

(2007) stated that the positive allometric growth implies the fish becomes relatively stouter or deeper-bodied as it increases in length and is indicated by a $b > 3.0$. *C. zillii* showed positive allometric growth in some waters, such as $b = 3.228$ in Umhfein Lake, Libya (Hadi, 2008), 3.496 in Gbedikere Lake, Nigeria (Adeyemi and Akombo, 2012) and 3.237 in the Garmat Ali River (Mohamed and Al-Wan, 2020). Whereas, some authors reported negative allometric growth for this species in other waters, for example, Negassa and Getahun (2003), Ibrahim *et al.* (2008), Sholloof (2009), Mahomoud *et al.* (2011), Mahmoud *et al.* (2013) and Efitre *et al.* (2016). However, other studies found isometric growth for *C. zillii* in different waters (Saleh, 1972; Mehanna, 2004; Mahmoud and Mazrouh, 2008). The growth of *O. aureus* also exhibited positive allometric growth in different natural waters in the world, such as in Wadi El-Raiyan Lakes, Egypt (Mehanna, 2004), in Euphrates River, Hindia dam (Hussain *et al.*, 2017), in Pinarbaşı Spring Creek, Turkey (Innal and Giannetto, 2017) and in the Garmat Ali River (Mohamed and Al-Wan, 2020). On the other hand, some authors working on the same species report-

ed negative allometric growth (Jiménez-Badillo, 2006; Mahmoud and Mazrouh, 2008; Messina *et al.*, 2010). These variations could be attributed to various factors like number and size of specimen examined, stomach fullness, sex variation, disease and parasite loads, stage of maturity, the method of sampling and the variations in the environmental conditions among different geographical localities (Bagenal and Tesch, 1978; Gokce *et al.*, 2007; Mir *et al.*, 2012; Cuadrado *et al.*, 2019). The growth parameters of the von Bertalanffy growth model computed by applying the ELEFAN I module implemented in FiSAT II for the present species are shown in Table 1 along with those reported by other authors for other fish species in various aquatic bodies. In general, the growth and mortality parameters estimated for *O. aureus* were higher than those documented for *C. zillii* in the present study. It is also clear that the values of growth parameters were different among various geographic localities for the same species. The asymptotic length (L_{∞}) for *C. zillii* in the present study was better than those recorded for the species in some waters (Mahmoud and Mazrouh, 2008; Mahmoud *et al.*, 2011; El-Bokhty and El-Far, 2014),

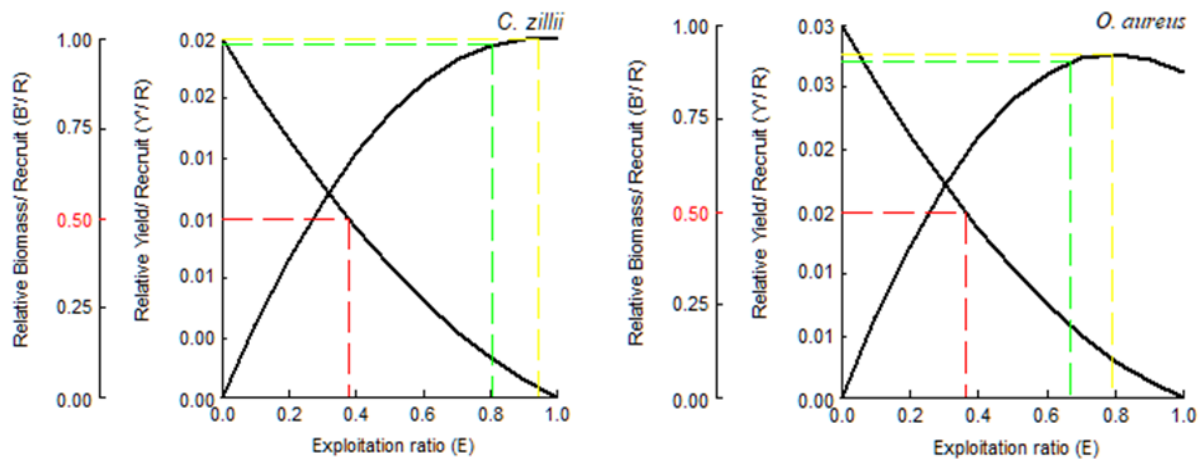


Fig. 9. Relative yield per recruit (Y/R) and biomass per recruit (B/R) analyses for *C. zillii* and *O. aureus*.

whereas, it was lower than those found in other waters (Mehanna, 2004; Mahomoud *et al.*, 2013; Uneke and Nwani, 2014). However, Mohamed and Al-Wan (2020) pointed out that the value of L_{∞} of *C. zillii* in the Garmat Ali River, Iraq was 28.4 cm. On the other hand, the L_{∞} value of *O. aureus* in this study was similar to those obtained by Mehanna (2004) for the species in Wadi El-Raiyan Lakes, Egypt and Mahmoud and Mazrouh (2008) in the Rosetta branch of the Nile River, Egypt (Table 1), while it was lower than those reported by Messina *et al.* (2010) and Mahmoud *et al.*

(2013) in the Aguamilpa Reservoir, Mexico and the Nozha Hydrodrome, Egypt, respectively. Moreover, L_{∞} value of *O. aureus* in the Garmat Ali River was found to be 28.4 cm (Al-wan and Mohamed, 2019). The values of K , t_0 , L_c and ϕ of *C. zillii* and *O. aureus* in the present study were intermediate with other values for the two species in other waters (Table 1). This variability in the growth of the same species in different locations could be attributed to several factors, such as ecological conditions, habitat, availability of food, metabolic activity, re-

Table 1. Population parameters of *C. zillii* and *O. aureus* in different aquatic bodies.

Location	L_{∞}	K	t_0	ϕ	L_c	Z	M	F	E	Author
<i>C. zillii</i>										
Wadi EL-Raiyan Lakes, Egypt	33.5	0.49	-0.15	2.74	11.5	1.10	0.20	0.90	0.82	Mehanna (2004)
Rosetta branch, Nile River	16.5	0.50	-0.15	2.13	7.5	2.41	1.09	1.32	0.55	Mahmoud & Mazrouh (2008)
Lake Timsah, Egypt	M 22.1 F 17.8	0.32 0.68	-1.41 -0.30	2.19 2.34	-	2.66 1.88	0.46 0.38	2.19 1.50	0.83 0.78	Mahomoud <i>et al.</i> (2011)
Nozha Hydrodrome, Egypt	33.4	0.20	-0.35	2.36	13.0	0.83	0.53	0.30	0.37	Mahmoud <i>et al.</i> (2013)
Cross River basin, Nigeria	27.8	0.46	-	-	11.9	3.16	1.14	2.02	0.64	Uneke & Nwani (2014)
Aswan, Nile River, Egypt	19.4	1.4	-	-	13.4	5.60	2.38	3.22	0.57	El-Bokhty & El-Far (2014)
Shatt Al-Arab River	25.5	0.32	-0.79	2.32	13.0	1.51	0.84	0.68	0.45	Present study
<i>O. aureus</i>										
Wadi EL-Raiyan Lakes, Egypt	27.2	0.56	-0.32	2.62	15.3	1.69	0.25	1.44	0.85	Mehanna (2004)
Rosetta branch, Nile River	26.4	0.40	-0.21	2.45	10.5	2.13	0.83	1.30	0.61	Mahmoud & Mazrouh (2008)
Aguamilpa Reservoir, Mexico	43.3	0.36	-0.41	2.83	-	1.94	0.83	1.10	0.57	Messina <i>et al.</i> (2010)
Nozha Hydrodrome, Egypt	38.1	0.21	-0.25	2.48	13.2	0.85	0.51	0.34	0.40	Mahmoud <i>et al.</i> (2013)
Shatt Al-Arab River	27.8	0.49	-0.27	2.58	13.3	2.49	1.08	1.41	0.57	Present study

productive activity, sizes of fish, method of sampling and fishing pressure (Nikolsky, 1963; Shal-loof and El-Far, 2009; Mahmoud *et al.*, 2013; Panda *et al.*, 2018). Wootton (2011) stated that the growth of an individual fish achieves on three constraints, the genetic constitution of the individual, the abiotic environment experienced by the fish will set constraints on growth and the biotic environment.

According to the present study, the present exploitation rates (E_{present}) were found to be 0.45 as in case of *C. zillii* and 0.57 for *O. aureus* indicating that the *C. zillii* was slightly under the optimum level of exploitation, whereas *O. aureus* was slightly under overexploitation. Gulland (1971) suggested that in an optimal exploited stock, fishing mortality should be about equal to natural mortality, resulting in an exploitation rate of 0.5, whereas less than 0.5 refers to under exploitation and greater than 0.5 refers to overexploitation. On the other hand, it was found that the exploitation rate of the two species in all the previous studies of different authors (Table 1) are higher than 0.5, except in the Nozha Hydrodrome, Egypt where, it was 0.37 for *C. zillii* and 0.40 for *O. aureus* (Mahmoud *et al.*, 2013), these results indicate that, the stocks of the two species under study are a target species and are suffering from a high rate of exploitation in the different geographic localities.

The recruitment pattern of *C. zillii* was recruited from January to July, but exhibited peak between February-May, whereas the recruitment pattern of *O. aureus* was continuous throughout the year, but showed peak between May to July. Jiménez-Badillo (2006) 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 recruitment of *C. zillii* was found to have two recruitment peaks in a year and the peaks overlapped in time to give a continuous year-round pattern in Bontanga Reservoir, Ghana (Kwarfo-Apegyah and Ofori-Danson, 2010), in the Ogun estuary, Nigeria (Abdul and Omoniyi, 2011) and in the mid-Cross River basin, Nigeria (Uneke and Nwani, 2014). There is no published report on the recruitment of *O. aureus* to the comparison. However, it has been reported that *O. aureus* has two peaks of the gonado-somatic index (GSI) in the Garmat Ali River, Iraq, the highest one was in April thereafter as a sign of the continuous release of eggs, and the second peak in September (Al-Wan and Mohamed, 2019).

Using the knife-edge selection procedure for the analysis of relative yield per recruit and the fishing mortality for *C. zillii* gave an $E_{\text{present}} = 0.454$, $E_{0.1} = 0.751$ and $E_{\text{max}} = 0.938$, and for *O. aureus* 0.570,

0.668 and 0.791, respectively. These revealed that both cichlid species understudy did not reach the target reference points, indicating that these species were not over exploited. Similar findings have been observed in *C. zillii* and *O. aureus* stocks in some waters, such as in the Rosetta branch of the Nile River, Egypt (Mahmoud and Mazrouh, 2008), in Ogun estuary, Nigeria (Abdul and Omoniyi, 2011), in Nozha Hydrodrome, Alexandria, Egypt (Mahmoud *et al.*, 2013), in the River Nile, Aswan region, Egypt (El-Bokhty and El-Far, 2014), in the mid-Cross River basin, Nigeria (Uneke and Nwani, 2014). Conversely, other studies found that *C. zillii* and *O. aureus* were overexploited, such as in Wadi El-Raiyan Lakes, Egypt (Mehanna, 2004), in the Aguamilpa Reservoir, Mexico (Messina *et al.*, 2010), in the Lake Timsah, Egypt (Mahomoud *et al.*, 2011).

Conclusion

The invasive cichlid species are now well established and dominated species in many Iraqi waters. However, the tilapias are not popular table fish in Iraq may be due to their novelty in waters of Iraq or their relatively unimportant sizes compared to exotic and indigenous cyprinids. Moreover, the stocks of tilapias in this study did not reach the target reference points, indicating that these species were not being overexploited. For management purposes, more yields could be obtained by the increase in the fishing activities on tilapias, such as increasing the number of fishing boats and decreasing the mesh-size for substantial harvest for their use as animal forage or export.

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