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ORIGINAL RESEARCH ARTICLE

Population dynamics of an invasive species *Carassius auratus* in the Shatt Al-Arab River, Iraq

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ABSTRACT

The population dynamics of the crucian carp, *Carassius auratus* in the Shatt Al-Arab River, Iraq was studied from November 2015 to October 2016 with monthly samples collected by different fishing gears. The FAO-ICLARM Stock Assessment Tool (FiSAT II) software was used for the mathematical analysis. Length-weight relationship was calculated as $W= 0.0149L^{3.065}$ for fish length 4.6 to 26.8 cm. Growth parameters L∞, K and Ø were computed as 29.1 cm, 0.51 and 2.635. The total (Z), natural (M) and fishing (F) mortalities were 2.69, 1.09 and 1.60, respectively. Exploitation rate (E) was 0.59. Length at first capture (L_c) was found to be 10.04 cm. *C. auratus* displayed one main pulse of annual recruitment. The relative yield per recruit analysis revealed that the exploitation rate (E) of *C. auratus* was higher than the biological target reference points $E_{0.1}$ and equivalent to E_{max}. It could be concluded that the *C. auratus* stock in the Shatt Al-Arab River is operating nearby the exploited situation and needs some precautionary measures to avoid the overexploitation by activating the national law of fishing, exploiting and protecting aquatic resources, in particular preventing illegal fishing methods and follow up the execution of the closed season to prevent the decline of our fish resources.

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INTRODUCTION

Crucian carp *Carassius auratus* (Linnaeus, 1758) is a member of the family Cyprinidae of order Cypriniformes. It is native to Eastern Asia which inhabit rivers, lakes, ponds and ditches with stagnant or slow-flowing water and has successfully established populations throughout Europe, North and South America, New Zealand and Australia (Lorenzoni *et al*., 2010). The crucian carp is an invasive species to inland waters of Iraq, it has invaded the country in a way that is not yet been known, however, Coad (2010) mentioned that this species has been introduced throughout Iranian waters including Khuzestan waters in the southwest of Iran, bordering Iraq, these fish can easily have crossed the border into Iraqi waters. Now, *C. auratus* is well established, easily became one of the dominant species and widespread throughout the different natural waters of the country. The species constituted 10.8% of the fish population in Euphrates River at Al-Mussaib Power Station (Al-Rudainy *et al*., 2006), 15.3% of fish in Al-Huwaizah marsh (Mohamed *et al*., 2008), 23.6% of fish in East Hammar marsh (Hussain *et al*., 2009), 20.0% of fish in Chybayish marsh (Mohamed *et al*., 2012a), 20.3% of fish in Shatt Al-Arab river (Mohamed *et al*., 2012b), 21.2%, of fish in Garmat Ali River (Mohamed *et al*., 2013), 352% of fish in Euphrates River at Al-Hindyah Barrier (Khaddara, 2014), 13.1% of fish in the East Hammar marsh (Mohamed *et al*., 2016), 13.2% of fish in the Shatt Al-Arab River (Mohamed and Abood, 2017) and 14.6% in fish in the Diwaniya River, middle of Iraq (Mohamed and Al-Jubouri, 2017).

The assessment of fish population is essential to meet one of the main objectives of fishery science, that of maximizing yield to fisheries, while safeguarding the long-term viability of populations and ecosystem (Jenning *et al*., 2000). Cooper (2007) stated that the stock assessment involves the application of statistical and mathematical methods to make quantitative statements about the status of fish populations and predictions about how they are likely to respond to alternative management choices. Few studies have been done on the population dynamics of *C. auratus* in various waters around the world using FiSAT II (FAO-ICLARM Stock Assessment Tools) software or length cohort analysis. Zhonghua *et al.* (1994) studied the growth and stock assessment of *C. auratus* in Wanghu Lake, China. Some biological aspects of *C. auratus* in the Euphrates River, middle of Iraq were described by Abbas *et al.* (2008). Al-Noor (2010) examined the population status of *C. auratus* in the East Hammar marsh, Iraq. The stock assessment of *C. auratus* in the East Hammar marsh has been studied by Mohamed *et al.* (2016). Hashemi *et al.* (2019) described the biological characteristics, growth parameters and mortality rate of *C. auratus* in the Shadegan Wetland, Iran.

Therefore, the present work covers growth parameters, mortality rates, and probability of capture, recruitment pattern and yield per recruit of *C. auratus* population in the Shatt Al-Arab River, to evaluate the population parameters required for proposing plans for managing the fish stocks in Iraqi waters.

MATERIALS AND METHODS

Fish sampling

Data were obtained from three sites on the Shatt Al-Arab River (Figure 1), near Al-Dair Bridge, Abu Al-Khasib district and north Fao town (Mohamed and Abood, 2017) from November 2015 to October 2016. Fish samples were regularly collected from each site by using gill nets (200-500 m length with 15- 35 mm mesh size), cast net (9 m diameter with 15×15 mm mesh size) and electro-fishing by generator engine (provides 300-400V and 10A).

Growth

Each fish was measured for total length (cm) and weighed to 0.1 g accuracy. Monthly length-frequency was compiled from the length measurements of fish samples. Data were grouped into classes with an interval of 1.0 cm to obtain a length-frequency table for analysis. For the estimation of length-weight relationship the power function was used (Le Cren, 1951): $W = a L^b$, where *W* is the weight of fish (g), *L* is the length of fish (cm), *a* is constant condition factor, and *b* is the slope. The relationship was established on Microsoft Excel version 10.

Length-frequency data of *C. auratus* were analysed by FISAT II (FAO-ICLARM stock assessment tool, Gayanilo *et al.*, 2005) for the estimation of growth and mortality parameters. The ELEFAN I procedure in FISAT II was then used to sequentially arrange and restructure the monthly frequency data set. The K-scan routine from the FISAT II program provided estimates of L_∞ and K. The estimate of theoretical age at length zero (t_0) was obtained by using the empirical equation of Pauly (1983).

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

The growth performance index (Ø') based on the length-frequency data was computed according to the formula of Pauly and Munro (1984) as $Ø' = \log_{10} K + 2 \log_{10} L_\infty$.

Mortality rates and recruitment pattern

The total mortality (Z) of *C. auratus* was estimated using FiSAT II (Gayanilo *et al.*, 2005) from linearized length-converted catch curve analysis of the length-frequency data. The natural mortality coefficient (M) was estimated using the formula suggested by Pauly (1980) as follows: $\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.463 \log_{10}$, where the mean water temperature (T) was 24.6 °C (Mohamed and Abood, 2017). The fishing mortality coefficient (F) was estimated as F= Z-M and the exploitation rate (E) was estimated using the formula of Gulland (1971) as E= F/Z.

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 was obtained by backward projection on the long 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 *C. auratus* using the knife-edge analysis of Beverton and Holt (1966) as modified by Pauly and Soriano (1986) and incorporated in FiSAT software. The data of L_c/L_∞ and M/K values were used to estimate E_{max}, $E_{0.1}$ and $E_{0.5}$. The current exploitation rate (E) and the biological target reference points ($E_{0.1}$ and E_{max}) were used to indicate the stock status (Cadima, 2003).

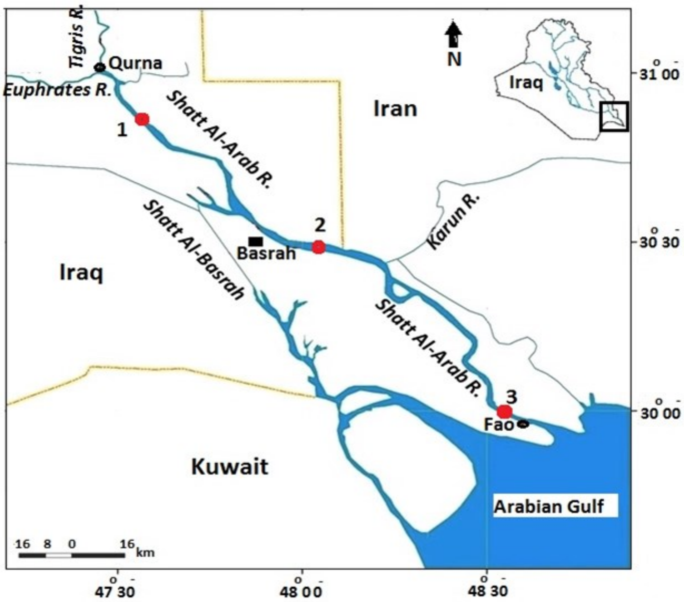

Figure 1. *Map of Shatt Al-Arab with locations of study sites.*

RESULTS AND DISCUSSION

Growth

The monthly samples of 1511 specimens of *C. auratus* were pooled to produce a single length frequency distribution (Figure 2). Fish length ranged from 4.0 to 26.0 cm and the major peak was at length 15 cm forming17.3% from the species population. The length groups that contributed to being the bulk of the catch ranged from 12 to 16 cm forming 67.5%.

The lengths of individual's of *C. auratus* in the present study was found to be almost similar to those recorded by Zhonghua *et al.* (1994) from Wanghu Lake, China (5.6-24.3 cm), Abbas *et al.* (2008) from Euphrates River at Al-Mussaib Power Station (6.2–25.5 cm) and Wahab (2013) from Al-Tharthar arm, Tigris river (13.0-26.6 cm). However, the size of *C. auratus* in this study was lower than those reported by Al-Noor (2010) from the East Hammar marsh (2.0-31.0 cm), Lorenzoni *et al.* (2010) from Lake Trasimeno, Italy (4.3-40.6 cm), Mohamed *et al.* (2016) in the East Hammar marsh (2.3 to 34.5 cm) and Mohamed and Al-Jubouri (2019) in the Al-Diwaniya River, Middle of Iraq (7.0-30.0 cm). This may be related to several factors such as water condition, food supply, population density, fishing pressure and possibly using different fishing gears (Nikolsky, 1963).

A total of 567 specimens of *C. auratus* with the size ranging between 4.6 to 26.8 cm were considered for the study of the length-weight relationship (Figure 3). The relationship provided a good fit for the speciesdata as, $W= 0.0149L^{3.065}$, (r = 0.993). The t-test revealed that the regression slope was significantly different from the theoretical value (t = 5.875, $P<0.05$) indicating positive allometric growth. Riedel *et al.* (2007) stated that the positive allometric growth indicates that the fish becomes relatively stouter or deeper-bodied as it increases in length and is indicated by a b >3.0. The result of the length-weight relationship in this study exhibited positive allometric pattern for *C. auratus*. Several studies demonstrated similar findings for the species in some waters, such as b= 3.085 in the East Hammar marsh (Mohamed *et al.*, 2016), 3.130 for males and 3.150 for females of the species in the Shadegan Wetland, Iran (Hashemi *et al.*, 2019) and 3.129 in the Al-Diwaniya River (Mohamed and Al-Jubouri, 2019). While, some authors reported negative allometric growth for this species in other waters, for example, Abbas *et al.* (2008) in the Euphrates River (b= 2.84 for males 2.95 for females) and Birecikligil *et al.* (2016) in the Kizılırmak River Basin, Turkey (b= 2.731). Al-Noor (2010) stated that the growth of *C. auratus* in the East Hammar marsh was isometric (b= 2.987). Various factors can be responsible for these differences such as fish sizes, stomach fullness, gender, diseases, maturity and environmental conditions between different geographical locations (Bagenal and Tesch, 1978; Gokce *et al.*, 2007; Cuadrado *et al.*, 2019).

The growth parameters of von Bertalanffy growth formula for *C. auratus* were estimated as L∞= 29.1cm and K = 0.51. For these estimates through ELEFAN I the response surface (R_n) was 0.271 for the curve (Figure 4). The computed growth curves produced with those parameters are shown over its restructured length distribution in Figure 5. The t_o was estimated as -0.239 years and the calculated growth performance index (Ǿ) was found to be 2.635. The yearly growth curve of *C. auratus* using The model of Bertalanffy growth modelof *C. auratus* could be written as $Lt= 29.1 (1-e^{-0.51 (t+0.239)})$. The growth parameters of *C. auratus* in this study were computed by applying the FiSAT II software are presented in Table 1 along with those reported by other authors who used the same technique or length cohort analysis (Jones, 1984). The asymptotic length (L∞) for *C. auratus* in the present study was better than those recorded for the species in some waters (Zhonghua *et al.*, 1994; Abbas *et al.*, 2008), whereas was lower than those found in other waters (Mohamed *et al.*, 2016; Hashemi *et al.*, 2019). In general, the estimated growth coefficient (K) for *C. auratus* in this study was higher than those documented for the species by other studies (Table 1). The dissimilarity in the growth parameters of the same species in different locations could be attributed to several factors, such as different environmental conditions, availability of food, reproductive activity and sizes of fish (Nikolsky, 1963; Sparre and Venema, 1998; Wootton, 2011).

Table 1. Comparison of growth and mortality parameters of *C. auratus* in different regions.

Location	L∞ (cm)	K	t_o	ø	Z	M	F	E	Source
Wanghu Lake, China	28.6	0.26	-0.12	-	0.96	0.61	0.35	0.36	Zhonghua *et al.* (1994)
Euphrates River, Iraq	27.9	0.36	-0.10	-	1.20	0.75	0.4	0.38	Abbas *et al.* (2008)
East Hammar marsh, Iraq	-	-	-	-	0.92	0.62	0.30	0.33	Al-Noor (2010)
East Hammar marsh, Iraq	42.3	0.27	-0.14	2.97	1.87	0.65	1.22	0.65	Mohamed *et al.* (2016)
Shadegan Wetland, Iran	34.6	0.36	-0.23	-	1.52	0.75	0.77	0.51	Hashemi *et al.* (2019)
Shatt Al-Arab River, Iraq	29.1	0.51	-0.24	2.64	2.69	1.09	1.60	0.59	Present study

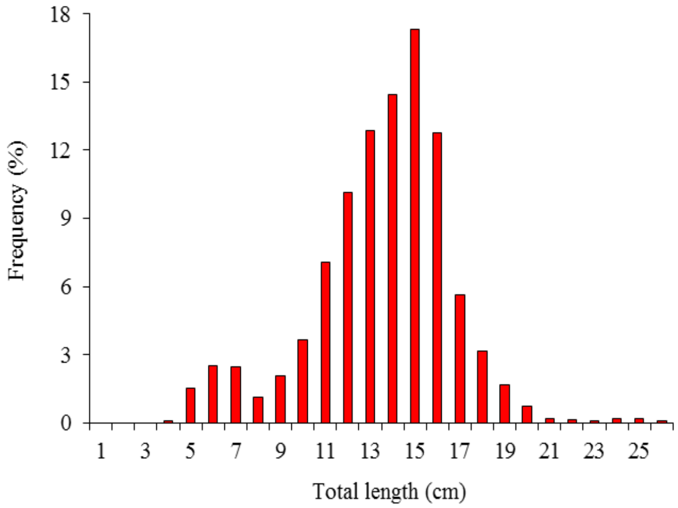

Figure 2. *The overall length frequencies of C. auratus.*

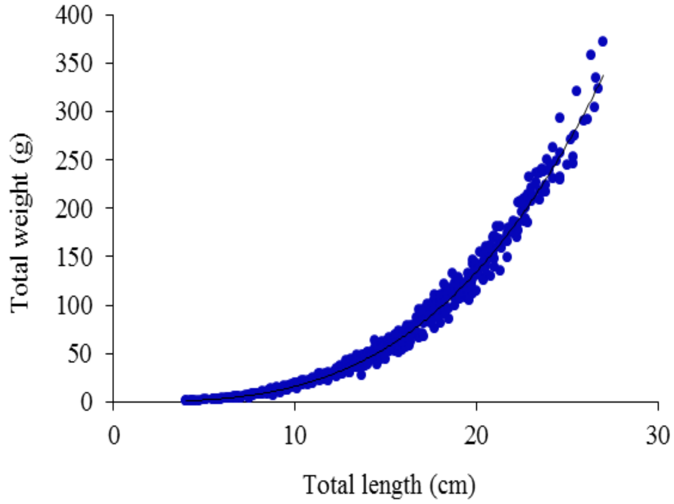

Figure 3. *The length-weight relationships of C. auratus.*

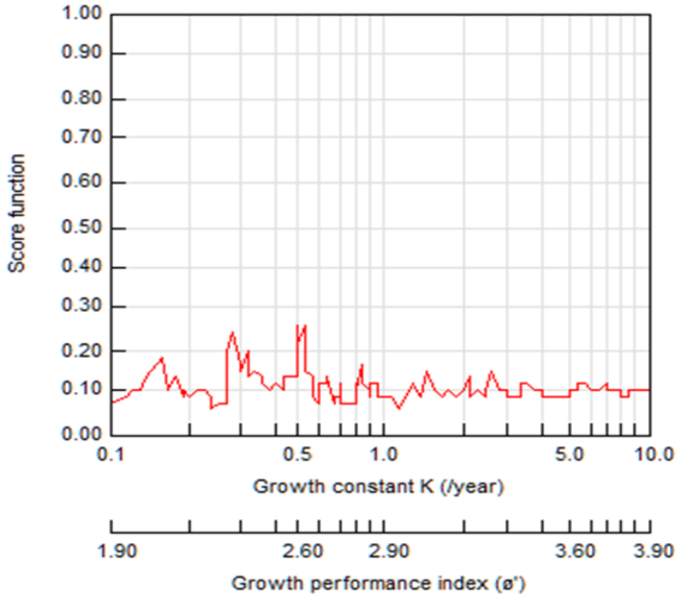

Figure 4. *K-scan routines of C. auratus.*

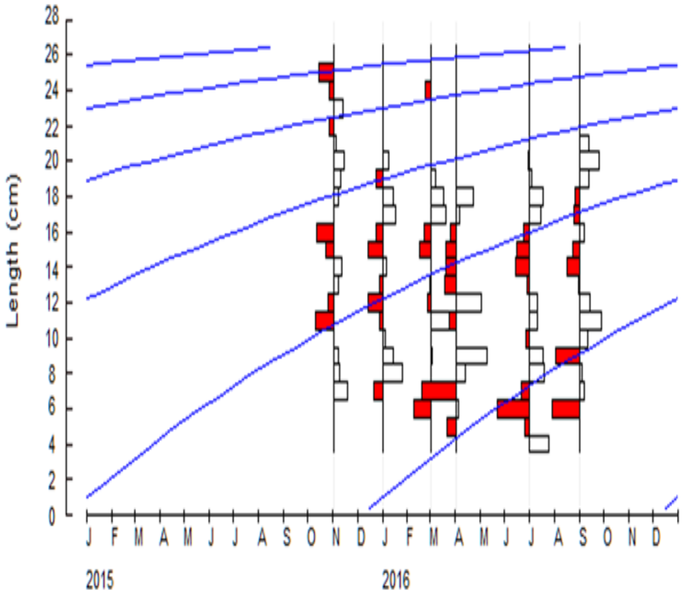

Figure 5. *Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for C. auratus.*

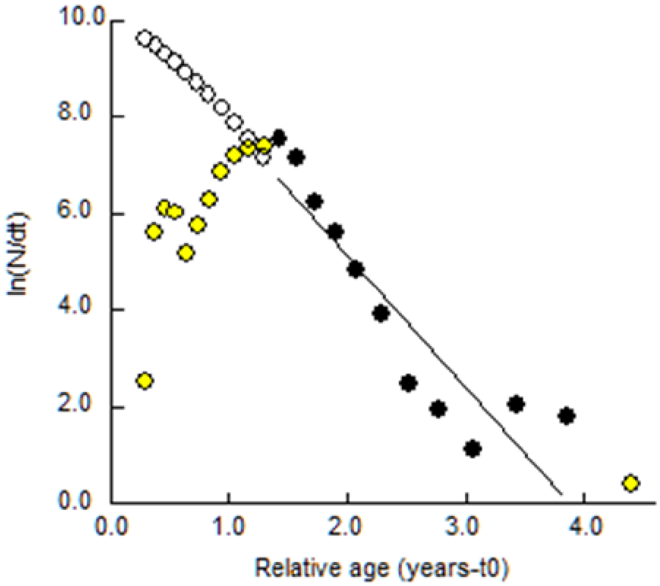

Figure 6. *Length converted catch curves of C. auratus.*

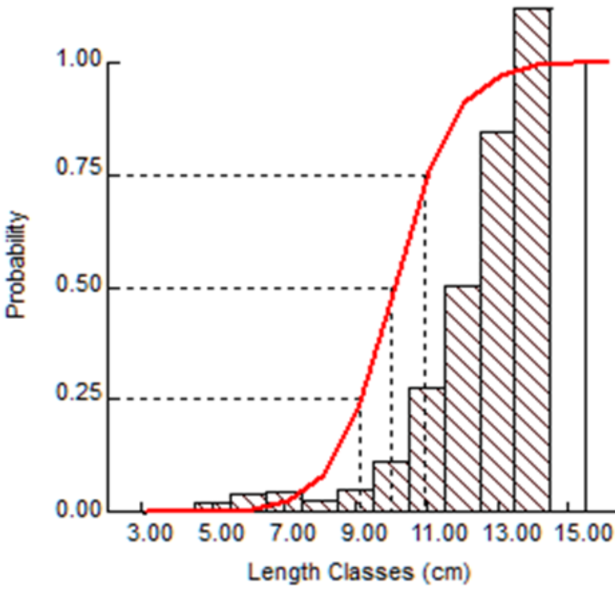

Figure 7. *Probability of capture for C. auratus.*

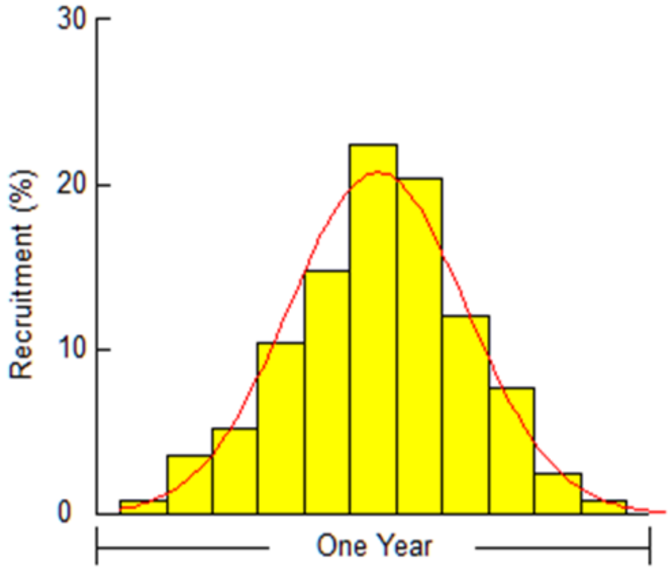

Figure 8. *Recruitment patterns of C. auratus.*

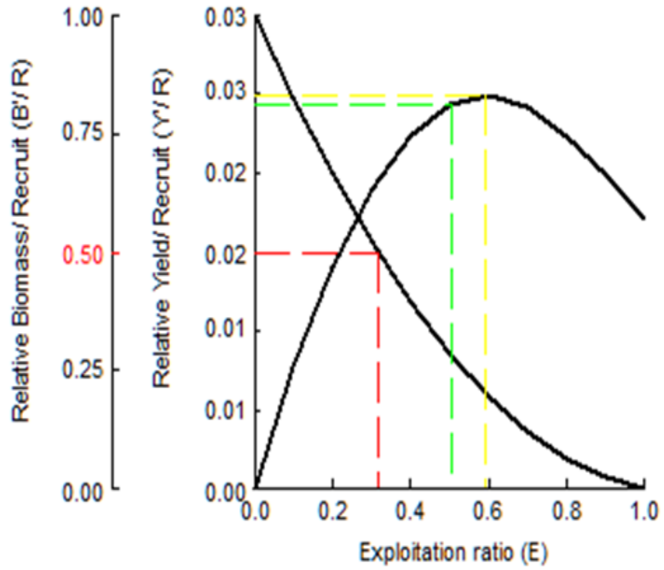

Figure 9. *Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for C. auratus.*

Mortality and exploitation rates

Figure 6 represents the catch curve utilized in the estimation of the annual rate of total mortality (Z) for *C. auratus*. The values of (Z) and natural mortality rate (M) were 2.69 and 1.09, respectively. The fishing mortality rate (F) was taken by subtracting (M) from (Z) and was found to be 1.60. From these results, the present exploitation rate ($E_{present}$) for *C. auratus* was computed to be 0.59. The values of both fishing mortality and exploitation rates are relatively high indicating a high level of exploitation. The length at first capture (the length at which 50% of the fish are vulnerable to capture) for *C. auratus* was estimated as a component of the length converted catch curve analysis (FiSAT II). The value obtained was L_{50}= 10.04 cm, whereas, the values of L_{25} and L_{75} were 9.11 and 10.97 cm, respectively (Figure 7).

The population of *C. auratus* in the Shatt Al-Arab River was overexploitation ($E_{present}$ = 0.59), since Gulland (1971) stated 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. Similar findings were recorded earlier by other workers in Table 1 (Mohamed *et al*., 2016; Hashemi *et al*., 2019), whereas was under exploitation in other waters (Zhonghua *et al*., 1994; Abbas *et al*., 2008; Al-Noor, 2010).

Recruitment pattern

The recruitment pattern of the stock of *C. auratus* from the Shatt Al-Arab River suggests that there is only one main pulse of annual recruitment (Figure 8) extended from April to September, which accounts to 87.4% of the recruits with the peak in June (22.21%). A similar trend was also observed in the study of Mohamed *et al*. (2016) for the same species in the East Hammar marsh.

Yield per recruit (Y'/R)

The relative yield-per-recruit (Y'/R) was determined as a function of M/K and L_c/L_∞, throughthe knife-edge selection routine of FiSAT-II. The M/K value is 2.137 and L_c/L_∞ value are 0.350 for *C. auratus* (Figure 9). The produced values of E_{max}= 0.591, $E_{0.1}$= 0.503, and $E_{0.5}$= 0.317 for *C. auratus*.

Based on the relative yield per recruit analysis, the biological target reference points were given, corresponding to $E_{0.1}$= 0.503 and E_{max}= 0.591. Since the present exploitation rate ($E_{present}$= 0.59) was higher than $E_{0.1}$ and equivalent to E_{max}, the stock of *C. auratus* in the Shatt Al-Arab River was considered as in a status of nearby overfishing. Similar findings have been observed in the stock of *C. auratus* in the East Hammar marsh (Mohamed *et al*., 2016), where the actual exploitation rate (0.65) was higher than the values of both $E_{0.1}$ (0.42) and E_{max} (0.52).

Conclusion

It could be concluded that the *C. auratus* stock in the Shatt Al-Arab River is operating nearby its exploited situation and needs some precautionary measures to avoid the overexploitation by activating the national law of fishing, exploiting and protecting aquatic resources, in particular preventing illegal fishing methods and follow up the execution of the closed season to prevent the decline of our fish resources.

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