



Aspects of Population Dynamics of Tiger Tooth Croaker, *Otolithes ruber* (Bloch and Schneider, 1801) from Northwest Arabian Gulf, Iraq

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Authors' contributions

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

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ABSTRACT

The present study consists of the growth, mortality, relative yield recruit and virtual population analysis of tigertooth croaker, *Otolithes ruber* from Iraqi marine waters, northwest Arabian Gulf between February 2020 and January 2021. Analysis of population dynamics employed methods fitted in FiSAT II software using pooled length-frequencies. A total of 3835 individuals of *O. ruber* ranged from 17.0 to 60.0 cm have been collected. The exponent (b) of the length-weight relationship was found to be 2.755. The von Bertalanffy growth parameters (L_{∞} and K) were estimated as 68.5 cm and 0.36, respectively, while the growth performance index (ϕ') was 3.228. The total mortality (Z) was calculated as 1.10, while the natural and fishing mortality rates were 0.69 and 0.41, respectively, and the current exploitation rate (E_{current}) was 0.38. Fish were recruited to the fishery at a mean size of $L_{50} = 20.55$ cm. The recruitment pattern of *O. ruber* was continuous throughout the year with two major peaks. The analysis of yield-per-recruit (Y/R') indicates that the current exploitation rate was below the biological target reference points ($E_{0.1} = 0.40$ and $E_{\text{max}} = 0.53$), refer to the stock of *O. ruber* is underexploited. The 27 cm length group was more vulnerable to fishing and more harvested according to virtual population analysis. sLength at first capture was higher than the length at first maturity of the species in the region. For management purposes, more yields could be obtained by increasing the mesh sizes of the nets employed in the fishing of the species.

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Keywords: *Otolithes ruber*; growth and mortality; yield-per-recruit; VPA; Arabian gulf.

1. INTRODUCTION

Sciaenidae is distributed worldwide in tropical and subtropical coastal waters and estuarine waters of the Atlantic, Indian, and Pacific oceans, which constitutes 293 species belonging to 69 genera and consider one of the largest families of the Order Perciformes [1,2].

Sciaenidae is one of the most common fish families in the Iraqi artisanal marine fisheries in the northwest of the Arabian Gulf and the most abundant sciaenid species are tigertooth croaker, *Otolithes ruber*, sin croaker, *Johnnieops sina* (synonym of *Johnius dussumieri*), silvery croaker, *Johnius belangerii* and blotched croaker, *Johnius maculatus* [3]. The total landing of these species was about 568 tons during 2019 which is about 5.02% of the total Iraqi marine landings [3]. However, six species of sciaenid fish were recorded from the Shatt Al-Arab River namely *J. belangerii*, *J. dussumieri* (*Johnieops sina*), *P. diacanthus*, *P. anea*, *O. ruber* and *J. sp.*, contributing around 6.5% of the fish assemblage in this river, and the first two species locally called as 'Taateo' were the most dominant in the river [4].

The tiger tooth croaker (*O. ruber*), locally known "Newaiby", is widely distributed in the Arabian Gulf and eastern coast of Africa, eastward to the coast of India and east Indies, Philippines, South China Sea, eastward to Fiji and southward to the northern coast of Australia [5]. Many studies have been conducted on population dynamics of *O. ruber* in different marine regions of the world using ELEFAN I or FISAT II (FAO-ICLARM Stock Assessment Tools) software such as [6] in Sofala Bank, Mozambique; [7] in the Arabian Gulf, Kuwait; [8] in the Arabian Gulf (Bushehr waters), Iran; [9] in Khoozestan province in the north of Arabian Gulf, Iran; [10] in the Thoothukudi coast, Tamil Nadu, India; [11] in the northwest of Oman Sea, Iran; [12] in the Balochistan coast, Pakistan and [13] in the Malindi-Ungwana bays, Kenya.

The stock assessment of *O. ruber* in Iraqi marine waters, northwest Arabian Gulf using FISAT II software was studied by Mohamed et al. [14], Ali et al. [15] and Resen et al. [16].

The tigertooth croaker is the most important commercial sciaenid species in Iraqi marine waters. Therefore, the present study was undertaken to generate information on the stock status such as growth parameters, mortality rates, probability of capture, recruitment pattern, yield per recruit and virtual population analysis of the species in Iraqi marine waters, northwest Arabian Gulf to derive requisite information for the sustainable management of the species.

2. MATERIALS AND METHODS

The Iraqi marine waters occupy the most northwestern tip of the Arabian Gulf comprises the Shatt Al-Arab estuary and several open lagoons such as Khor Al-Khafga, Khor Al-Umaya, Khor Al-Rocka and Khor Abdullah [17]. Despite the restriction of the Iraqi coastline 105km, continental shelf 1034 km² and territorial sea 716 km² [18] but considered the most productive area in the Gulf due to the run of the Shatt Al-Arab River [19]. The surface water temperature values ranged from 12.4°C in January to 37.2°C in June, and salinity varied from 28.1‰ in November to 47.3‰ in July [20]. Fig. 1 illustrates the main fishing grounds for Iraqi marine fisheries, include the Shatt Al-Arab estuary, Khor Abdulla and Khor Al-Amaya [21]. The fishermen employed different fishing gears such as drift gillnets, trawl nets, traps (gargoor), stake nets (hadra) and hook and line [22]. Al-Fao port considers the main centre of landings and auction of Iraqi marine resources locates on the tip of the northwest Arabian Gulf.

Monthly random samples of *O. ruber* were obtained during the period from February 2020 to January 2021 (except April) from the Shaheen steel-hulled dhow (21 m length, 7 m wide and 2m draft with a horsepower of 150 horses) and from the artisanal fishermen at the main fish landings site in Al-Fao port. During this study, a total length of 3835 specimens of *O. ruber* was measured in the field to the estimation of growth and population parameters. Subsamples of fish were immediately iced and transported to the laboratory for measuring the weight (to the nearest 0.5 g) and length (to the nearest 1.0 mm) of each specimen.

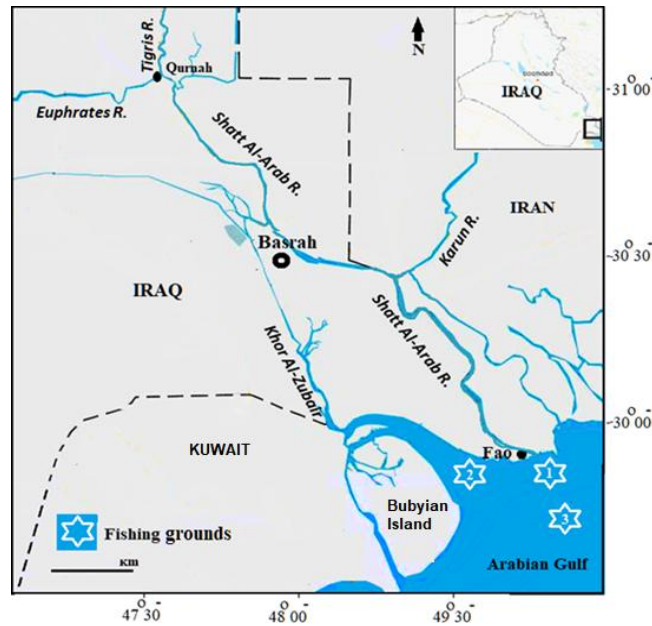


Fig. 1. Fishing grounds in Iraqi marine waters, northwest Arabian Gulf

The length-weight relationship was described through Microsoft Excel version 10 by the following potential regression equation $W = a * L^b$ [23], where the intercept and b are the growth coefficient. To compare the difference of parameter b from 3, a t-test was used to test the significant difference [24].

The length-frequency data of 3835 specimens of the species in the total length range of 17-60 cm were grouped into 3.0 cm class intervals, sequentially arranged according to a time series of 11 months and stored in the FiSAT II package [25]. The asymptotic length (L_{∞}) and growth coefficient (K) were estimated by input data from length frequencies and the ELEFANT-I program. ELEFANT I routine of FiSAT II attempts to combine the logic of the Peterson method and that of modal progression analysis with a minimum of subjective inputs [26]. To find the best growth curve passing through the maximum number of peaks, different starting samples and starting lengths were subjected to goodness-of-fit tests by assessing the ESP/ASP ratio (R_n). The value of (t_0) was estimated by substituted the L_{∞} and K in the following equation [26]:

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

The growth performance index (ϕ') was estimated from an empirical equation by Pauly and Munro [27]:

$$\phi' = \log_{10} K + 2 \log_{10} L_{\infty}$$

From the estimate of growth parameters (K and L_{∞}), the instantaneous rate of annual total mortality (Z) was estimated using the length converted catch analysis method [26] incorporated in the FiSAT package and selecting the best points on the straight line of the right arm of the curve. The instantaneous rate of natural mortality (M) was obtained using Pauly's empirical formula (1980) as implemented in the FiSAT II, considering the mean annual water temperature of 24.8°C [20]:

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} T$$

$$K + 0.463 \log_{10} T$$

The fishing mortality coefficient (F) was computed by the difference between (Z) and (M), while the current exploitation ratio (E_{current}) was estimated by the ratio between (F) and (Z) [28]. The inbuilt logits method as implemented in the FiSAT II was employed 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 recruitment pulses per year and their relative strength were determined from the routine implemented in FiSAT II software using the time series length-frequency data set and the growth parameters (L_{∞} and K), which involves the backward projection of length frequencies onto time axis based on growth parameters [26]. The knife-edge analysis of Beverton and Holt [29] as modified by Pauly and Soriano [30] and

incorporated in the FiSAT package was employed to analyze the relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) using data of L_c/L_∞ , M/K and E values as input parameters. The procedure for estimating Y'/R and B'/R gave estimates of biological referenced points ($E_{0.1}$ and E_{max}), where $E_{0.1}$ is the exploitation rate at which the marginal increase of relative yield-per-recruit is 1/10th of its value at $E=0$ and E_{max} is the exploitation rate which produces maximum yield. The biological target reference points ($E_{0.1}$ and E_{max}) were compared with the current rate of exploitation ($E_{current}$) and used to determine the status of the species stock [31].

Length-structured virtual population analysis (VPA), which allows the reconstruction of the population from total catch data by length was carried out by the method of Jones and van Zalinge [32] and incorporated in the FiSAT package to determine the array of (F) for each length class. The estimates of L_∞ , K, M, F, a and b (constants of length-weight relationship) for the species were used as inputs to VPA analysis for the species concerned.

3. RESULTS

3.1 Growth

Fig. 2 explains the annual length-frequency distribution of 3835 individuals of *O. ruber* that have been collected from February 2020 to January 2021. Length frequency was assembling in length groups with 3 cm interval, ranges in total length from 17 cm weighing approximately 67 g while the largest size was 60 cm (1714 g). Amongst these, over 62.5% of the catch ranged in length between 20 to 34 cm. More importantly, the length group 26 cm composed about 5.4% of the total catch.

Based on 264 individuals of *O. ruber*, their total length size and weight range were from 17 to 60 cm and 67 to 1714 g, respectively. The length-weight relationship has been computed for combined sexes (Fig. 3) and the equation obtained is:

$$W = 0.023L^{2.755}, \quad r^2 = 0.993$$

The total length-weight relationship of the species indicated that this relationship is highly significant ($p < 0.05$) with a high r^2 value (0.993) which indicate an increase in length with an increase in weight. The exponent ($b = 2.755$) was

significantly different from value 3 ($t = 16.86$, $P < 0.05$), indicating that growth in this species is negatively allometric.

By applying the ELEFAN I analysis in FiSAT II software, the optimized VBG curve yielded the following growth estimate with the K-scan (Fig. 4): $L_\infty = 68.5$ cm, $K = 0.36$ and $R_n = 0.229$. These curves superimposed over the length-frequency histograms represent restructured length-frequency histograms (Fig. 5). The t_0 was calculated as -0.320 years. The growth performance index (ϕ') was estimated as 3.228.

3.2 Mortality and Exploitation Rates

The length-converted catch curve for *O. ruber* to estimate the annual total mortality rate (Z) is shown in Fig. 6. The darkened circles represent the points used in estimation (Z) that was 1.10 with 95% of the confidence interval (0.97-1.22; $r^2 = 0.973$). The natural mortality coefficient (M) was determined by Pauly empirical equation and was 0.69, while the fishing mortality (F) was taken by subtraction of M from Z and was 0.41. The current exploitation rate ($E_{current}$) computed as $F/Z = 0.38$.

3.3 Probability of Capture

Fig. 7 shows the probabilities of the capture of each size class obtained by backward extrapolation of the straight portion of the right descending part of the catch curve in FiSAT software. The selection length of 25% or L_{25} was 19.22 cm, 50% or L_{50} was 20.55 cm and the 75% or L_{75} was 21.89 cm.

3.4 Recruitment

As shown in Fig. 8, the annual recruitment pattern of *O. ruber* indicated that recruitment occurred throughout the year with two prominent peaks of different magnitudes. The major one occurred from June to September with a peak in August (15.62%), while the minor one happened from January to April with a peak in March (9.31%).

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

Fig. 9 shows the values of yield per recruit and the biomass per recruit, which analyzed by the knife-edge selection routine in the Beverton and Holt Y/R model incorporated in FiSAT software as a function of M/K (1.917) and L_c/L_∞ (0.301),

which derived from the previous analyses. Consequently, the estimated values of target reference points ($E_{0.1}$ and E_{max}) were 0.402 and 0.529, respectively, and this revealed that the current exploitation rate ($E_{current} = 0.38$) was lower than both biological target reference points. The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were 0.018 and 0.071, respectively.

3.6 Virtual Population Analysis

The results of virtual population analysis (VPA) are presented in Table 2 and Fig. 10. From Table 1, the catches ranged from 11, length class 15cm, to 543, length class 27cm. The length classes of 21cm to 51cm have been mostly exploited in the fishery. However, the 27 cm length group was more vulnerable to fishing,

which has more harvested according to VPA analysis, followed by 24 cm and 21 cm length groups. Recruitment of *O. ruber* into the fishery estimated at 12769.73. The population of fish decreased with the increased length class. Fishing mortality was high for length groups 21 cm (0.28/y) to 57 cm (1.10/y). The average fishing mortality value of *O. ruber* was 0.477/year, and this was slightly high than that estimated by catch-curve, 0.41/year. Steady-state biomass increased with mid-length, from 15cm (0.23 ton) to 39cm (1.01 ton), then fell to 0.16 ton for mid-length 60 cm. The natural losses and survivability of the fish population decreased with an increase in length and fishing mortality (Fig. 3). The maximum value of fishing mortality ($F = 1.10$) noticed was at a total length of 57 cm, after which there was a sudden decline in F .

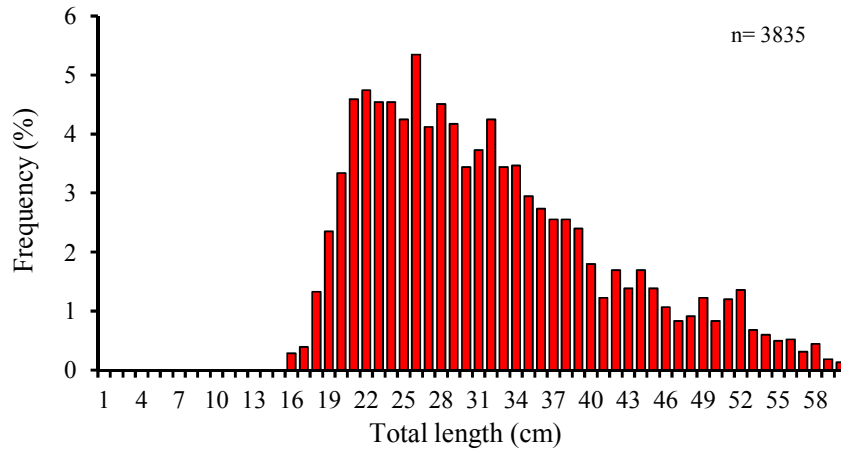


Fig. 2. The annual length-frequency distribution of *O. ruber*

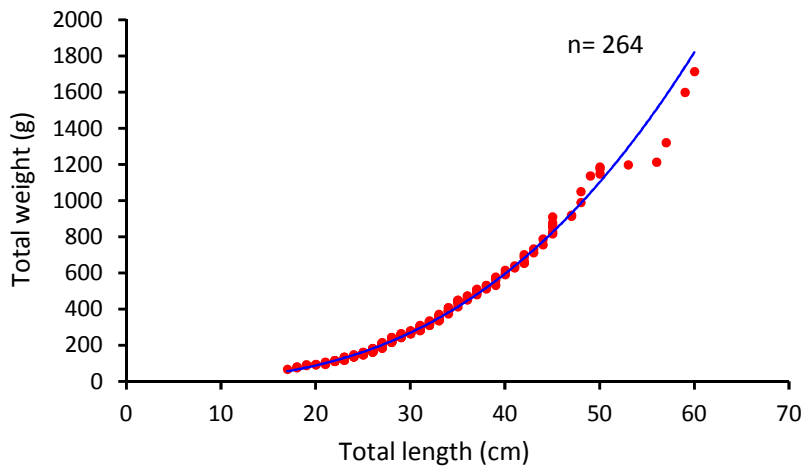


Fig. 3. The length-weight relationship of *O. ruber*

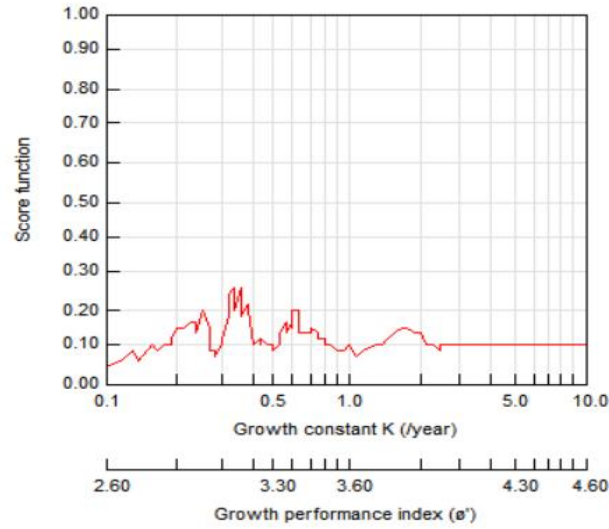


Fig. 4. K-scan routines of *O. ruber*

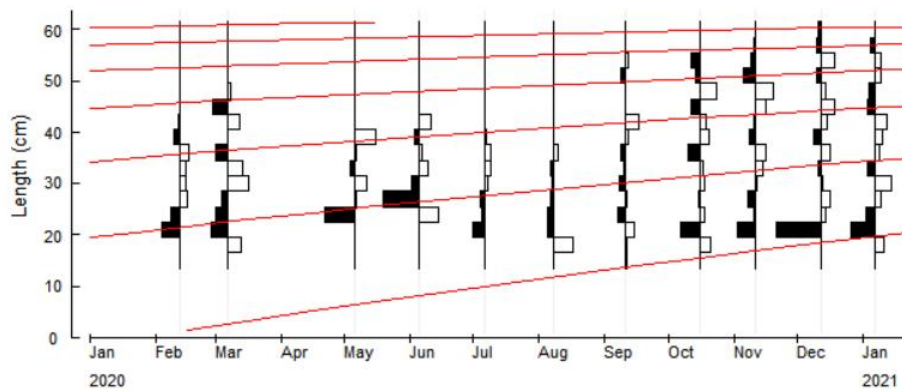


Fig. 5. Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *O. ruber*.

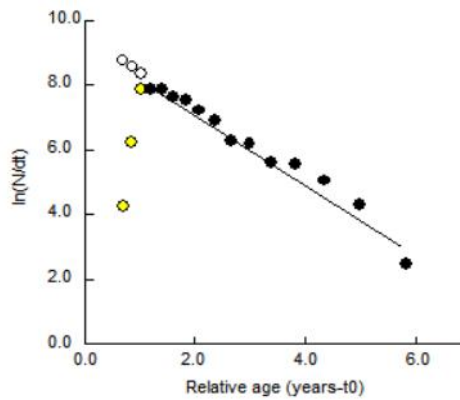


Fig. 6. Length converted catch curve for estimation of Z for *O. ruber*

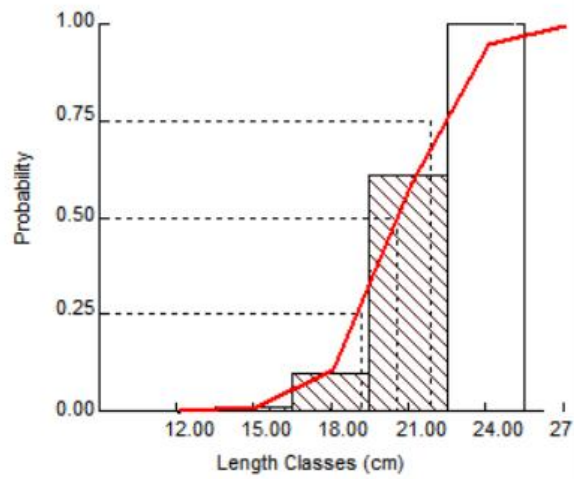


Fig. 7. Probability of capture for *O. ruber*

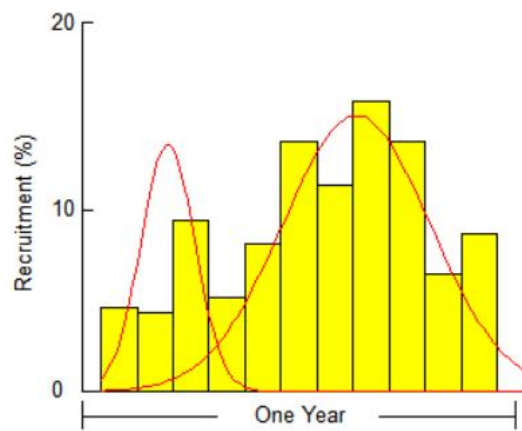


Fig. 8. Recruitment pattern of *O. ruber*

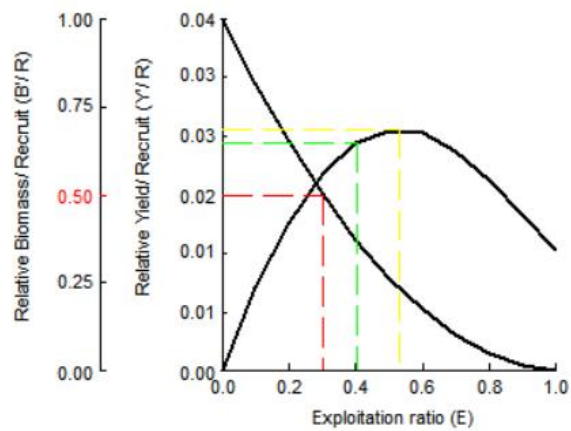


Fig. 9. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for *O. ruber*

Table 1. FiSAT II output of virtual population analysis of *O. ruber* from Iraqi marine waters

| Length class (cm) | Catch (numbers) | Population (N) | Fishing mortality (F) | Steady-state Biomass (tons) |
|-------------------|-----------------|----------------|-----------------------|-----------------------------|
| 15.0 | 11.00 | 12769.73 | 0.0058 | 0.23 |
| 18.0 | 86.00 | 11457.72 | 0.0483 | 0.36 |
| 21.0 | 458.00 | 10143.13 | 0.2798 | 0.50 |
| 24.0 | 493.00 | 8555.70 | 0.3382 | 0.64 |
| 27.0 | 543.00 | 7056.75 | 0.4276 | 0.77 |
| 30.0 | 452.00 | 5637.62 | 0.4163 | 0.88 |
| 33.0 | 440.00 | 4436.52 | 0.4831 | 0.96 |
| 36.0 | 356.00 | 3368.05 | 0.4767 | 1.00 |
| 39.0 | 284.00 | 2496.71 | 0.4720 | 1.01 |
| 42.0 | 171.00 | 1797.57 | 0.3546 | 0.99 |
| 45.0 | 176.00 | 1293.81 | 0.4672 | 0.93 |
| 48.0 | 112.00 | 857.86 | 0.3968 | 0.84 |
| 51.0 | 128.00 | 551.08 | 0.6601 | 0.68 |
| 54.0 | 92.00 | 289.28 | 0.8274 | 0.46 |
| 57.0 | 54.00 | 120.56 | 1.1003 | 0.23 |
| 60.0 | 12.00 | 32.70 | 0.4000 | 0.16 |
| Mean | | | 0.477 | |

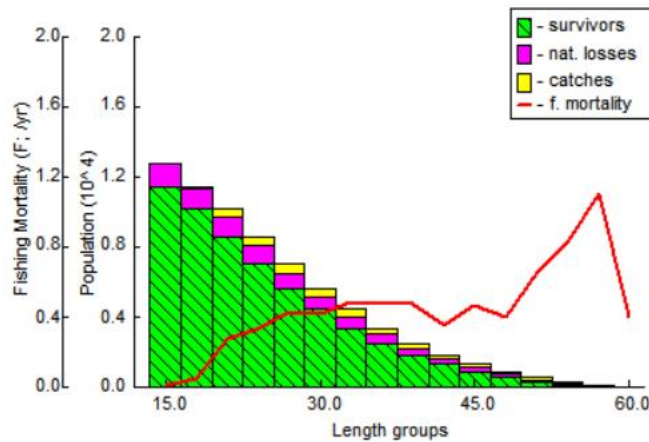


Fig. 10. Length-structured virtual population analysis of *O. ruber* from Iraqi marine waters

4. DISCUSSION AND CONCLUSION

Pope et al. [33] stated that the estimates of population dynamics can indicate how a population arrived at its current state and how it might change in the future. Kebtieneh et al. [34] stated that the basic purpose of stock assessment is to provide decision-makers with the information necessary to make rational choices on the optimum level of exploitation of aquatic living resources such as fish.

Table 3 compares the size range of *O. ruber* obtained in this study with those obtained by the various authors in different geographic localities. It is clear that the size range of *O. ruber* in the

present study (17-60 cm) was within the values documented for the species in the other local studies [15,16], whereas, was larger than those reported by other authors in other regions [6,7,35,9,36,37,10-13], which are ranging from 33.0 cm in Balochistan coast, Pakistan [12] to 59.0 cm in northwestern Arabian Gulf, Iran [9, 36]. These differences may be associated with differences among fishing gear used and different ecological conditions of these habitats [38,39].

According to Froese [40], the growth coefficient (b) of the length-weight relationship should normally fall between 2.5 and 3.5. Moreover, Riedel et al. [39] stated if the value of b is 3.0

indicates that the growth is isometric, or higher than 3.0 refers to positive allometric growth, or when lower than 3.0 means negative allometric. The values of growth coefficient (b) of *O. ruber* recorded in various geographic localities are presented in Table 2 and exhibited different growth types. The growth of the species in the present study was negatively allometric, i.e. the fish becomes lighter for its corresponding length, and showed similar growth with some studies [14,16,36], while other studies demonstrated isometric growth [37,10-12]. The length-weight relationship in fish can be affected by various factors such as habitat, season, stage of fish maturity, sex, food availability, stomach fullness, health, stress, and sampling methodology [24,40,41].

Table 3 compares the growth parameters (L_{∞} , K and \emptyset) for *O. ruber* obtained in this study with those obtained from other studies by applying the length cohort analysis [42] or ELEFAN 1 or FiSAT II software. The obtained values of these parameters found here are within the ranges observed in other populations of *O. ruber*. Baloch et al. [12] noted the lowest value of L_{∞} (34.7 cm) for the species in the Balochistan coast, Pakistan, while Resen et al. [16] recorded the highest value (71.9 cm) in northwestern Arabian Gulf, Iraq. The growth coefficient (K) extended from 0.26 in northwestern Arabian Gulf, Kuwait [43] to 0.83 in Balochistan coast, Pakistan [12]. The values of \emptyset for *O. ruber* varied from 2.61 [12] to 3.24 [11], and the estimate obtained in our study (3.23) compares with the higher end of this range. The variations in the growth parameters of the same species in different geographic locations may depend on several factors, such as the environmental conditions, sampling methodology, availability of food, reproductive activity, the genetic constitution of the individual and fishing pressure [38, 44-46].

The rates of the total mortality (Z), natural mortality (M), fishing mortality (F) and the current exploitation (E_{current}) of *O. ruber* recorded in various geographic localities are given in Table 2. It can observe that all rates within the ranges recorded in other populations of *O. ruber*. Mohamed et al. [14] recorded the lowest value of Z (0.86) for the species in northwestern Arabian Gulf, Iraq, while the highest value (3.23) was observed in Malindi-Ungwana Bay, Kenya [13]. Natural mortality (M) ranged from 0.55 in northwestern Arabian Gulf, Iraq [15] to 1.47 in Balochistan coast, Pakistan [12]. The fishing mortality rate for *O. ruber* varied from 0.27 in,

Iraq [14] to 2.71 in the Balochistan coast, Pakistan [12]. The lowest values of exploitation rate (E) of the species observed in Iraqi and Kuwaiti.

Waters, northwestern Arabian Gulf as compare with other regions. Mohamed et al. [14] recorded the lowest value of E (0.31) for the species in northwestern Arabian Gulf, Iraq, while the highest value (0.71) was observed in Thoothukudi Coast, India [10] and in Malindi-Ungwana Bay, Kenya [13]. The optimum level of exploitation is 0.5 when fishing mortality is equal to the natural one [28]. So, the obtained value of exploitation rate (E_{current}) in the present study (0.38) was lower than the optimum level reflecting the low level of fishing pressure on this species.

The recruitment pattern of *O. ruber* in the present study reveals that the major pulse takes place during June-September with a peak in August and the minor one during January-April with a peak in March. The recruitment pattern has concerned with the spawning time [47]. Dadzie [48] found one distinct spawning period for *O. ruber* in the northwestern Arabian Gulf extended from January to May. A similar trend has also observed by some authors. Ali et al. [15] noted that *O. ruber* in the Iraqi marine waters exhibited two peaks of unequal magnitude, with the major peak occurring in May and the minor in November. Also, Mzingirwa et al. [13] stated that the recruitment pattern of *O. ruber* in Malindi-Ungwana Bay, Kenya showed two unequal recruitment pulses, with the major peak occurring in August and the minor in March.

Analysis of the relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) of *O. ruber* using the knife-edge selection revealed that the values of target reference points ($E_{0.1}$ and E_{max}) were 0.402 and 0.529, respectively, and this revealed that the actual exploitation rate ($E_{\text{current}}=0.38$) was lower than both target reference points which indicates that the stock of the species is underexploited. Similar findings have been noticed for *O. ruber* stock in Iraqi marine waters by other authors. Ali et al. [15] reported that the values of the actual exploitation rate (E) and E_{max} were 0.38 and 0.40, respectively, and Resen et al. [16] pointed out that the values of the actual exploitation rate (E) and E_{max} for the species in the same waters were 0.36 and 0.44, respectively. Conversely, Schultz [6] pointed out that the stock of *O. ruber* in the Sofala Bank,

Table 2. Comparative data for length ranges and growth coefficient (b) of the length-weight relationship of *O. ruber* from different regions

| Authors | Length range (cm) | (b) | Region |
|---------------------------|-------------------|-------|-----------------------------------|
| Schultz [6] | 2.5-42.5 | - | Sofala Bank, Mozambique |
| Al-Matar [7] | 10.5-47.5 | - | Northwestern Arabian Gulf, Kuwait |
| Mohamed et al. [14] | 8.9-54.6 | 3.098 | Northwestern Arabian Gulf, Iraq |
| Ali et al. [15] | 7.5-65.0 | - | Northwestern Arabian Gulf, Iraq |
| Brash and Fennessy [35] | 8.4-48.5 | - | KwaZulu-Natal, South Africa |
| Khodadadi et al. [9] | 15.0-59.0 | - | Northwestern Arabian Gulf, Iran |
| Resen et al. [16] | 7.0 to 64.0 | 3.090 | Northwestern Arabian Gulf, Iraq |
| Eskandari et al. [36] | 6.0-59.0 | 3.190 | Northwestern Arabian Gulf, Iran |
| Raeisi et al. [37] | 29.6-50.1 | 2.890 | North Arabian Gulf, Iran |
| Santhoshkumar et al. [10] | 11.2-42.5 | 2.835 | Thoothukudi coast, India |
| Farkhondeh et al. [11] | 15.0-54.0 | 2.941 | Northwestern Oman Sea, Iran |
| Baloch et al. [12] | 3.0-33.0 | 2.839 | Balochistan coast, Pakistan |
| Mzingirwa et al. [13] | 5.0-38.4 | - | Malindi-Ungwana Bay, Kenya |
| Present study | 17.0-60.0 | 2.755 | Northwestern Arabian Gulf, Iraq |

Table 3. Comparison of population parameters of *O. ruber* from different areas of the world

| Author | L_{∞} | K | \emptyset | Z | M | F | $E_{current}$ | Location |
|---------------------------|--------------|------|-------------|------|------|------|---------------|-----------------------------------|
| Samuel and Morgan [43] | 63.0 | 0.26 | - | 1.5 | 1.0 | 0.5 | 0.33 | Northwestern Arabian Gulf, Kuwait |
| Schultz [43] | 45.9 | 0.32 | 2.84 | 1.95 | 0.70 | 1.25 | 0.64 | Sofala Bank, Mozambique |
| Al-Matar [43] | 59.0 | 0.38 | - | - | - | - | - | Northwestern Arabian Gulf, Kuwait |
| Mohamed et al. [14] | 58.9 | 0.28 | - | 0.56 | 0.59 | 0.27 | 0.31 | Northwestern Arabian Gulf, Iraq |
| Ali et al. [43] | 68.2 | 0.28 | - | 0.89 | 0.55 | 0.34 | 0.38 | Northwestern Arabian Gulf, Iraq |
| Niamaimandi [43] | 58.0 | 0.80 | - | 2.70 | 1.24 | 1.46 | 0.54 | North Arabian Gulf, Iran |
| Khodadadi et al. [43] | 64.9 | 0.4 | - | 1.95 | 0.7 | 1.25 | 0.64 | Northwestern Arabian Gulf, Iran |
| Resen et al. [43] | 71.9 | 0.28 | - | 0.91 | 0.58 | 0.33 | 0.36 | Northwestern Arabian Gulf, Iraq |
| Santhoshkumar et al. [43] | 37.3 | 0.27 | - | 2.45 | 0.71 | 1.74 | 0.71 | Thoothukudi Coast, India |
| Farkhondeh et al. [43] | 65.0 | 0.41 | 3.24 | 1.85 | 0.78 | 1.07 | 0.58 | Northwestern Oman Sea, Iran |
| Baloch et al. [43] | 34.7 | 0.83 | 2.61 | 3.18 | 1.47 | 2.71 | 0.68 | Balochistan coast, Pakistan |
| Mzingirwa et al. [43] | 41.7 | 0.79 | 3.09 | 3.23 | 0.93 | 2.3 | 0.71 | Malindi-Ungwana Bay, Kenya |
| Present study | 68.5 | 0.36 | 3.23 | 1.10 | 0.69 | 0.41 | 0.38 | Northwestern Arabian Gulf, Iraq |

Mozambique was overfished, where the values of E , $E_{0.1}$, $E_{0.5}$ and E_{max} were 0.64, 0.55, 0.33 and 0.64, respectively. Also, Mzingirwa et al. [13] noted that the species in the Malindi-Ungwana Bay, Kenya appears to be overexploited, where the actual exploitation rate ($E=0.71$) was higher than $E_{0.1}$ (0.54) and very close to E_{max} (0.78). However, Gulland [28] 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.

According to virtual population analysis (VPA), the 27 cm length group was more vulnerable to fishing and more harvested, followed by 24 cm and 21 cm length groups. Also, there was a large difference between the length at first capture ($L_{50}=20.6$ cm) and the length at first maturity (L_m), compared to the report of Eskandari et al. [36] who stated that the length at first maturity (L_m) of *O. ruber* in the northwest Arabian Gulf was 28.0 cm. Schultz [6] mentioned that the VPA analysis for the species in the Sofala Bank, Mozambique suggested that fishing mortality is relatively constant in the older fish. Recently, Baloch et al. [12] stated that the individuals of the species loss were at smaller length size fish, while fishing pressure was high from 16 to 33 cm, according to the VPA analysis for the species in the Balochistan coast, Pakistan.

The study revealed that the *O. ruber* stock in Iraqi marine waters was underexploited, and more individuals are caught before they reached length at first sexual maturity. Consequently, more yields could be obtained through a reasonable increase in the size of the first capture without necessarily leading to overexploitation. These could be achieved by increasing the mesh sizes of the nets for fishing this species. These results can be useful for officials in fishery management to sustain the population of *O. ruber* in Iraqi marine waters. Froese et al. [49] demonstrated that fishing within the L_{opt} range maximizes yield and spawning biomass and would be a step towards sustainable ecosystem-based fisheries management.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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