

Growth, Mortality and Yield-per-recruit of Nile Tilapia (*Oreochromis niloticus*) in Garmat Ali River, Iraq

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ABSTRACT---The study was conducted to estimate the growth, mortality, recruitment and yield-per-recruit of *Oreochromis niloticus* from Garmat Ali River, Basrah, Iraq from October 2019 to September 2020. The population parameters were analyzed using the FAO-ICLARM stock assessment tool (FiSAT). A total of 2696 *O. niloticus* ranged from 7.0 to 25.0 cm and the sizes 13.0-18.0 cm constituted 64.2% of the total catch. The length-weight relationship was $W=0.012L^{3.109}$ suggesting that the species shows positive allometric growth. The growth parameters for the species were estimated as $L_{\infty}=30.45$ cm, $K=0.45$, $t_0=-0.313$ and $\Theta=2.622$. The coefficients of total mortality (Z), natural mortality (M) and fishing mortality (F) were 3.26, 1.03 and 2.24, respectively. The exploitation rate for the species computed to be 0.69. Fish were recruited to the fishery at a mean size of $L_{50}=14.92$ cm. The peak of recruitment was 23.51% in June. The analysis of yield-per-recruit (Y/R') indicates that stock is not being overfished since the present exploitation rate was below the biological target reference points ($E_{0.1}$ and E_{max}). So, more yields could be achieved by reducing the mesh sizes of the nets for fishing the species.

Keywords-- Nile tilapia, growth and mortality, yield-per-recruit, Garmat Ali River, Iraq

1. INTRODUCTION

The Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) is indigenous to central and north Africa and the middle east [1]. It has a broad natural distribution spanning from the upper Nile river southwards to the equator and west to the Atlantic coast due to their environmental tolerance, successful reproductive strategies and trophic plasticity [2]. Zengeya et al. [3] reviewed the ecological tolerances of *O. niloticus* and stated it is tolerant to a wide range of temperatures (8-42°C) but their natural temperature range is 13.5-33.0°C and is tolerant to brackish water of salinity ranges from 20-30‰. *O. niloticus* has rapid growth rate, high resistance disease, high fecundity, hatching throughout the year and parental care, make the species breeding increasingly important in the world [4]. Consequently, it has been widely introduced elsewhere, both in Africa and other continents, including tens of countries in Asia, Europe, North America, Central America and South America [5]. The global production of tilapia was expected to continue to have risen by around 3–4 percent in 2018, reaching 6.3 million tones [6].

The population dynamics of *O. niloticus* have been assessed by several authors in different natural water bodies in the world over using FiSAT II (FAO-ICLARM Stock Assessment Tools) software such as Ahmed et al. [7] in the Kaptai Reservoir, Bangladesh; Njiru et al. [8] in the Kenyan portion of Lake Victoria; Novaes and Carvalho [9] in Barra Bonita Reservoir, Brazil; El-Bokhty and El-Far [10] in the Nile River, at Aswan region, Egypt; El-Kasheif et al. [11] in El-Bahr El-Faraouny Canal, Al-Minufiya Province, Egypt; Yongo and Outa [12] in the open waters of Lake Victoria, Kenya; Alemu et al. [13] in Lake Hawassa, Ethiopia; Ana Mehak et al. [14] in Chashma Barrage, Pakistan and Shija et al. [15] in Lake Chamo, Ethiopia.

O. niloticus is exotic fish to Iraqi waters and it was first reported from the Shatt Al-Arab River in late 2013 [16]. Currently, the species is well established in different natural waters of Iraq [17-22]. The other two cichlid fish in Iraqi waters are redbelly tilapia, *Coptodon zillii* and blue tilapia, *O. aureus* [19]. These cichlids species have become widespread and prevalent in many Iraqi waters. They constituted 10.5% of fish assembly in Shatt Al-Arab River [20], 9.4% of the fish assemblages in the East Hammar marsh [23], 21.3% of fish in the middle part of the Shatt Al-Arab River [19], 32.6% of fish in the lower reaches of Tigris River, north east of Basrah province [24], 21.9% of fish structure in the Al-Swab River, a tributary of the Shatt Al-Arab River [25], 32.3% of fish assemblage in Shatt Al-Arab River at Abu Al-Khasib district [21], and 38.5% of fish fauna in the Al-Kahlaa River, a tributary of the Tigris River, Missan province [26].

Several studies have been discussed the serious threat of invaded fish species on the stability of ecosystems, and the impacts of cichlids introduced on native fish and their habitats were well documented [27]. Simoes Vitule et al. [28]

mentioned that invasive freshwater species are often the culprits driving biodiversity loss, either directly through biotic interactions, or indirectly by affecting the availability of essential resources, facilitating the spread of infectious disease, or through hybridization with native taxa. Genner et al. [29] mentioned that *O. niloticus* was an important competitor and predator of native species, has potential to hybridize with indigenous *Oreochromis* species, and has been widely implicated in biodiversity loss globally. Moreover, Vicente and Fonseca-Alves [30] stated that the release of *O. niloticus* into non-native aquatic ecosystems may result in competition for food and space, thereby damaging native species. Consequently, it became necessary to compile information about the population status of these invaded cichlids in Iraqi waters. Recently, the population dynamics and management of two cichlid species (*C. zillii* and *O. aureus*) in Shatt Al-Arab River have been studied by Mohamed and Abood (2020) [31], and the present study is a continuation of investigation on tilapia fish in Iraq.

The main objective of this study is to estimate growth parameters, mortality rates, probability of capture, recruitment pattern and yield per recruit of *O. niloticus* 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 METHOD

Fish samples were collected from two sites on Garmat Ali river, north of Basrah city within the coordinates 30° 34' to 30° 35' N and 47° 43' to 47° 46' E (Fig. 1). The first site located near Al-Najeebia Bridge opposite the Naval Academy and the second site in the upper river area before its confluence with the East Hammar marsh. 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. The predominant vegetation on the banks was *Phragmites australis* and *Typha domingensis*, whereas *Ceratophyllum demersum* was dominant in the deeper areas.



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

The 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 an icebox and transported to the laboratory for subsequent analysis.

The total length was measured to the nearest mm for 2727 specimens of *O. niloticus*. The length frequency data were grouped into 1.0 cm class intervals, sequentially arranged according to a time series of 12 months, and stored in FiSAT II package [32] for subsequent analysis. A number of fish were measured with a precision of 1 mm and weight (W) with a precision of 0.5 g. The length-weight relationship was established on Microsoft Excel version 10 using the formula of $W = a \times L^b$ [33], 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 [34].

The length data were analyzed using the FiSAT (FAOICLARM Stock Assessment Tools) after Gayanilo et al. [32] in the computer software package. The Electronic Length Frequency Analysis (ELEFAN 1 module in FiSAT II) was used to estimate the von Bertalanffy growth function (VBGF) through understanding the seasonal oscillation along with the estimation of the L_{∞} , K and R_n . The predicted maximum length from extreme values was computed [35, 36]. The theoretical age at zero-length (t_0) was calculated using the empirical equation of Pauly [35]:

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

Growth performance index (ϕ') was calculated according to the formula of Pauly and Munro [37]: $\phi' = \log_{10}K + 2 \log_{10}L_{\infty}$.

The annual total mortality rate (Z) was estimated by the length-converted catch curve analysis method of Pauly [35] incorporated in FiSAT package using the input parameters L_{∞} and K , and selecting the best points on the straight line of the right arm of the curve. The instantaneous rate of natural mortality (M) was computed from the empirical equation of Pauly [38] considering the mean annual water temperature of the river as 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 (F) was obtained by the subtraction of M from Z and the exploitation rate (E) was calculated from the relationship: $E = F/Z$ [39]. The linearized catch curve used for estimating Z was extrapolated backward to the points of the descending part of the length converted 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 monthly recruitment pattern was reconstructed using the time series length-frequency data set and the growth parameters (L_{∞} and K) as described in FiSAT software package. This routine reconstructs the recruitment pulse from a time series of length-frequency data onto a 1-year time scale [40].

The model of Beverton and Holt [41], as modified by Pauly and Soriano [42] was used to predict the relative yield per recruit (Y/R) of the species to the fisheries. The calculations were done using the knife-edge method and the data of L_c/L_{∞} and M/K values as described in FiSAT software package to estimate $E_{0.1}$, $E_{0.5}$ and E_{max} . $E_{0.1}$ is a level of exploitation at which the marginal increase in yield per recruit reaches 1/10 of the marginal increase computed at a very low value of E , $E_{0.5}$ is the exploitation level associated with a 50% reduction of the biomass per recruit in the unexploited stock and E_{max} is sustainable exploitation level that produces the maximum yield. The biological target reference points, $E_{0.1}$ and E_{max} were compared with the current rate of exploitation (E) and used to determine the status of *O. niloticus* stock at the river [43].

3. RESULTS

3.1 Growth

The overall length-frequency distribution of *O. niloticus* from monthly samples is shown in figure 2. The sample composed of 2727 individuals ranging in total length from 7.0 to 25.0 cm. The most frequent length groups percentage of *O. niloticus* were 23.1 and 52.8% corresponding to length groups 8.0–11.0 and 14.0–17.0 cm, respectively. The population is dominated by middle-sized fish 13.0–18.0 cm constituted 66.1% of the total catch.

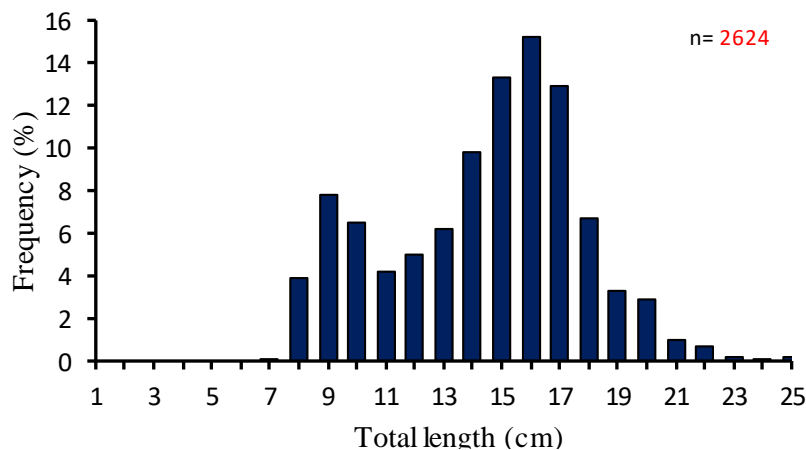


Figure 2: The overall length-frequency distribution of *O. niloticus*.

Length and weight measurements of 2050 specimens ranging from 8.0 to 25.5 cm in total length and weighing 8.0–325.0 g were used to describe the length-weight relationship of *O. niloticus* in the river (Fig. 3). The obtained equation was as follow:

$$W = 0.012L^{3.109}, \quad r^2 = 0.969$$

The confidence limit of (b) was 3.085-3.133 and the t-test revealed that the regression was significantly different from 3 ($t = 9.02, P < 0.05$), indicating positive allometric growth.

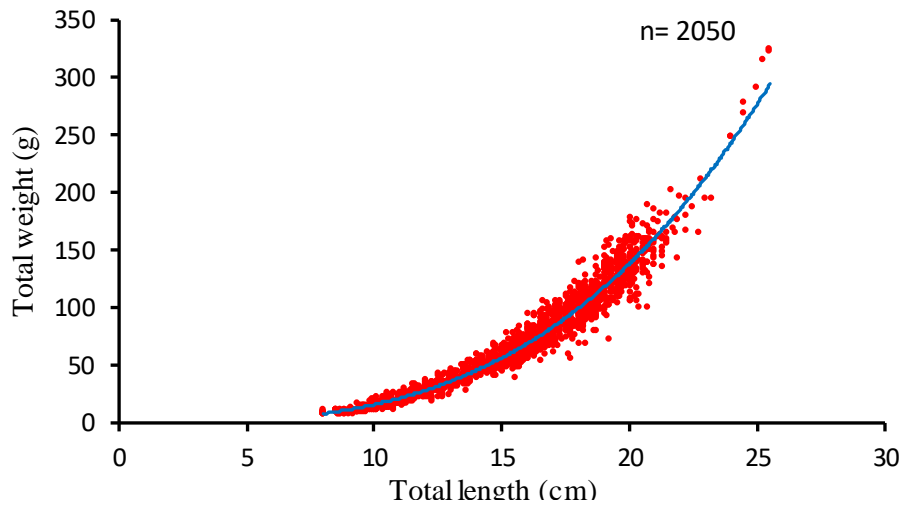


Figure 3: The length-weight relationship of *O. niloticus*.

The response surface (R_n) analysis of the FiSAT package (Fig. 4) and the ELEFAN I routine were used to scan for the best estimates of the asymptotic length (L_∞) and the growth constant (K), based on the restructured form of the length-frequency data for *O. niloticus* (Fig. 5). The growth parameters for the species were estimated as $L_\infty = 30.45$ cm and $K = 0.45$, while the estimated value of goodness of fit of model estimation $R_n = 0.225$. The t_0 was calculated as -0.313 years. The growth performance index (ϕ') was estimated as 2.622.

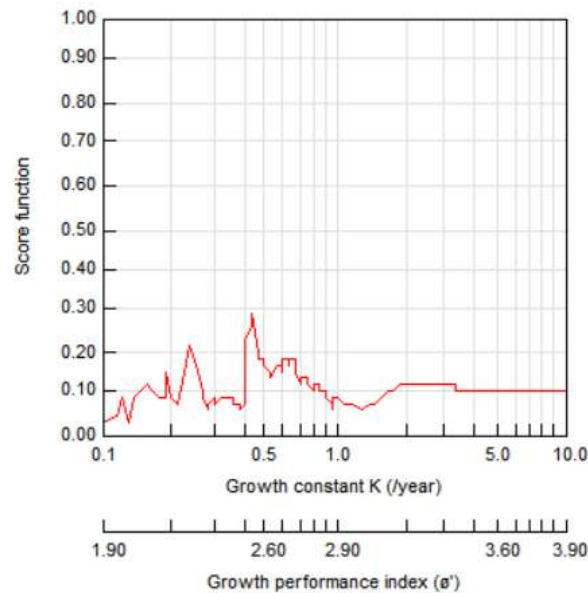


Figure 4: K-scan routines of *O. niloticus*.

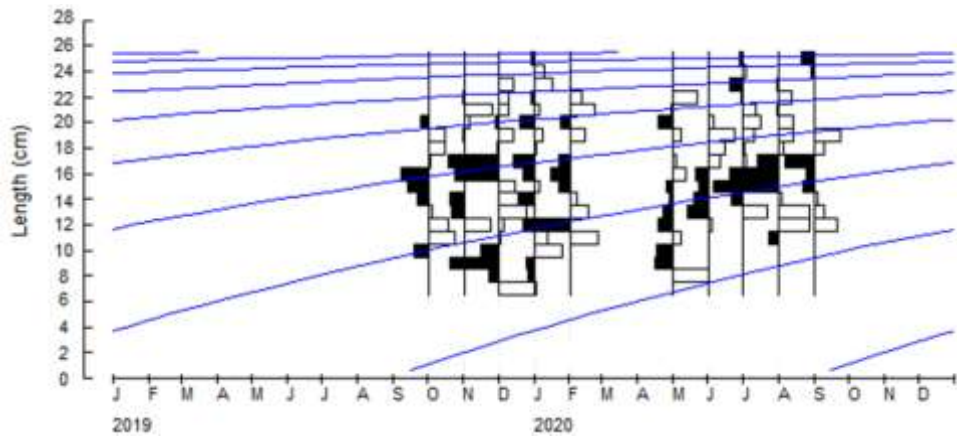


Figure 5: Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *O. niloticus*.

3.2 Mortality and exploitation rates

Figure 6 represents the catch curve utilized in the estimation of the total mortality (Z) of *O. niloticus* which was 3.26 (95% of confidence interval (CI) of $Z= 2.95-3.58$; standard deviation of the slope=0.609; $r= -0.994$). The natural mortality rate (M) was 1.03, while the rate of fishing mortality (F) was 2.24. Therefore, the present exploitation rate (E_{present}) was 0.69.

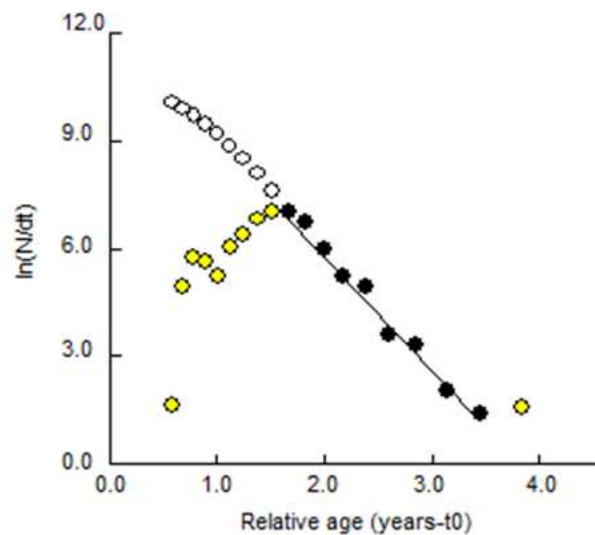


Figure 6: Length converted catch curves of *O. niloticus*.

3.3 Probability of capture

The probability of capture of *O. niloticus* was estimated as a component of the length converted catch curve analysis in FiSAT software (Fig. 7). The selection length of 25% or L_{25} was 13.64 cm, 50% or L_{50} was 14.92 cm and the 75% or L_{75} was 16.20 cm. Hence, fish appeared to be recruited to the fishery at a mean size of $L_{50}= 14.92$ cm.

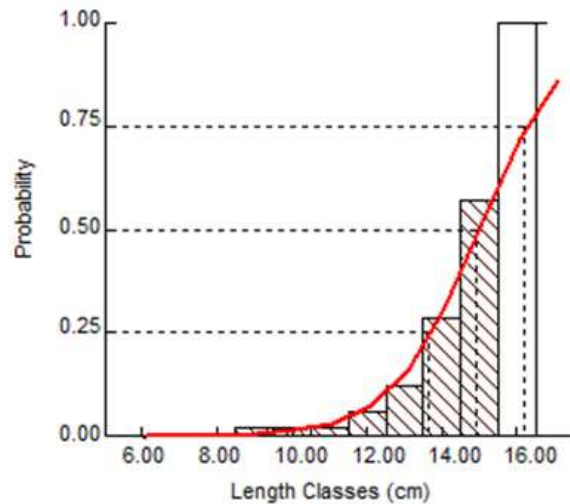


Figure 7: Probability of capture for *O. niloticus*.

3.4 Recruitment

It was found from the recruitment pattern that *O. niloticus* recruits almost throughout the year (Fig. 8). However, the main recruitment pulse was evident from April-July with a peak in June (23.51%).

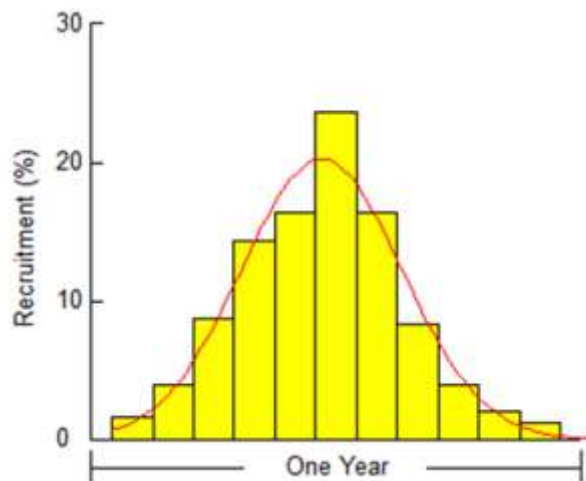


Figure 8: Recruitment pattern of *O. niloticus*.

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

The knife-edge selection routine in Beverton and Holt Y/R analyses incorporated in FiSAT package was adopted to predict the relative yield per recruit (Y'/R) of *O. niloticus*. Using the values of M/K (2.289) and L_c/L_∞ (0.490) as derived from the previous analyses, the estimate values of $E_{0.1}$, $E_{0.5}$ and E_{max} were 0.707, 0.365 and 0.824, respectively (Fig. 9). It is clear that the present exploitation rate ($E_{present}$) is lower than the biological target reference points ($E_{0.1}$ and E_{max}) for the species. The relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) were 0.024 and 0.220, respectively.

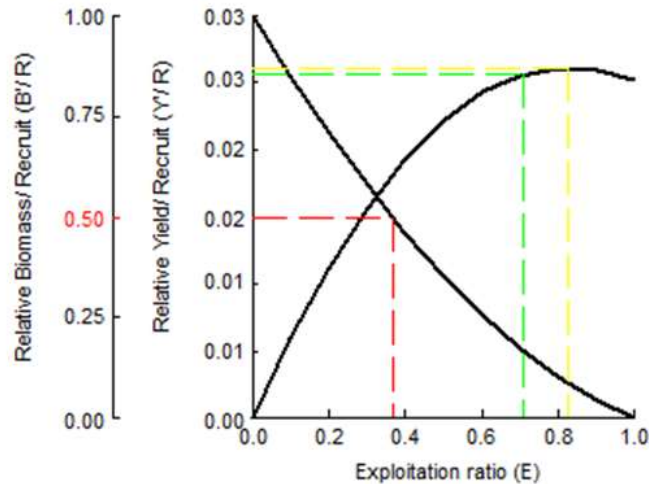


Figure 9: Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for *O. niloticus*.

4. DISCUSSION

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 [44]. The analysis of the length composition over the time of sampling revealed that all the captured individuals of *O. niloticus* have an average total length ranging from 7.0 to 25.0 cm. These sizes of fish were compared with those obtained by the various authors in different geographic localities (Table 1). It is clear that the length range of *O. niloticus* in the present study was comparable with those reported by other authors [46, 48, 49, 50, 52, 18, 54, 22, 58]. Conversely, other authors recorded higher values of length for this species in other waters [7, 46, 9, 50, 52, 11, 54, 55, 56]. These differences 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 [58-60].

Table (1): Comparative data for the growth coefficient (b) for *O. niloticus* in different ecosystems.

| Authors | Length range (cm) | (b) | Region |
|----------------------------|-------------------|-------|------------------------------------|
| Ahmed et al. [7] | 15.0-53.0 | 2.844 | Kaptai Reservoir, Bangladesh |
| El-Bokhtym [45] | 6.9-27.5 | 3.010 | Lake Manzala, Egypt |
| Bwanika et al. [46] | 3.7-52.5 | 3.117 | lakes Nabugabo and Wamala, Uganda |
| Mahmoud and Mazrouh [47] | 9.5-25.5 | 3.008 | Rosetta branch, Nile River, Egypt |
| Shalloof and El-Far [48] | 12.0-22.0 | 2.403 | Abu-Zaabal lakes, Egypt |
| Novaes and Carvalho [9] | 11.0-31.2 (SL) | 2.884 | Barra Bonita Reservoir, Brazil |
| Hirpo [49] | 8.0-25.0 | 2.690 | Lake Beseka, Ethiopia |
| Hassan and El-Kasheif [50] | 4.0-33.9 | 2.792 | River Nile, Beni Suef, Egypt |
| Mortuza and Al-Misned [51] | 6.9-27.3 | 3.080 | Wadi Hanifah, Saudi Arabia |
| Kembenya et al. [52] | 8.0-33.0 | 3.080 | Lake Baringo, Kenya |
| El-Kasheif et al. [11] | 4.8-33.6 | 2.001 | El-Bahr El-Faraouny Canal, Egypt |
| Khalifa [18] | 6.8-27.9 | 2.010 | Tigris River, south Baghdad, Iraq |
| Shalloof and El-Far [48] | 8.3-28.6 | 2.726 | Rosetta branch, River Nile, Egypt |
| | 10.8-26.1 | 3.063 | Damietta branch, River Nile, Egypt |
| Teame et al. [53] | 6.0-37.0 | 2.917 | Tekeze Reservoir, Ethiopia |
| Enawgaw and Lemma [54] | 2.5-30.9 | 2.900 | Lake Timishu Abaya, Ethiopia |
| Cuadrado et al. [55] | 11.4-36.1 | 3.138 | Lakes of Esperanza, Philippines |
| Negaud [22] | 4.5-26.0 | 3.210 | AL-Rumaitha River, Iraq |
| Mohamed and Al-Wan [56] | 6.9-23.2 | 3.077 | Garmat Ali river, Iraq |
| Present study | 8.0-25.5 | 3.109 | Garmat Ali river, Iraq |

The

length-weight relationship is an important tool in fishery management. Principally, the relationship can be used for conversion of growth in length equations to growth in weight equations in the stock assessment models, for estimation of yield and biomass of a fish population, for the comparison among geographical habitats and for predicting the general well-

being of fish population [33, 34, 61, 60, 62]. The growth coefficient (b) of length-weight relationship is different among various geographic localities for the same species as presented in Table 2. It is evident from the table that the b value of *O. niloticus* exhibited a different type of growth (isometric and negative or positive allometric) in various geographic locations, so it was ranged from 2.001 in the Pharaoh Sea Canal, Egypt and to 3.210 in Rumaitha River, Iraq. In the present study, $b > 3$, indicated positive allometric pattern of growth in *O. niloticus* that means large fish samples have grown more in weight than in length and robustness of large-sized specimens; or large samples were in good nutritional environments at sampling time [63]. Riedel et al. [60] stated that this type of growth implies the fish becomes relatively stouter or deeper-bodied as it increases in length. Several authors have also reported positive allometric growth for *O. niloticus* from various water bodies in the world [45, 46, 51, 52, 48, 55, 22, 56]. While other authors have been reported negative allometric growth for this species in other waters (Table 1). 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 [34, 64, 63, 55].

The results of growth parameters (L_{∞} , K, t_0 , \hat{O} and L_c) for *O. niloticus* in the current study and those reported from different geographic locations which were obtained by applying FiSAT II software are shown in Table 2. It is clear that the values of these parameters obtained here are well within the range reported for this species in other studies. El-Bokhty and El-Far recorded the lowest value of L_{∞} (25.7 cm) for *O. niloticus* in River Nile, Aswan, Egypt, whereas Ahmed et al. [7] found the highest value (55.6 cm) in Kaptai Reservoir, Bangladesh. Growth coefficient (K) ranged from 0.29 [11] to 0.73 [10] and t_0 from -0.467 [15] to 0.09 [11]. The values of \hat{O} for *O. niloticus* ranged from 2.61 [11] to 3.30 [8], and the estimate obtained in our study (2.62) compares with the lower end of this range. The estimated length at first capture (L_c) of *O. niloticus* was 15.5 cm. This is also in line with the results of the length-frequency distribution in which 13-18 cm size groups were numerically dominant and constituted 67.2% of the population. This result was nearly close to those reported by El-Bokhty and El-Far [10] and El-Kasheif et al. [11], whereas lower than other estimates as shown in Table 2. These differences in the growth of this species in different locations could be attributed to several factors, such as the environmental conditions, habitat, availability of food, metabolic activity, reproductive activity, the genetic constitution of the individual, fishing pressure and sampling method [58, 36, 65, 66].

Table 2: Comparison of population parameters of *O. niloticus* in different ecosystems.

| Author | L_{∞} | K | t_0 | \hat{O} | L_c | Z | M | F | E | Location |
|---------------------------|--------------|------|--------|-----------|-------|------|------|------|------|----------------------------------|
| Ahmed et al. [7] | 55.59 | 0.39 | - | 3.08 | 22.2 | 1.39 | 0.80 | 0.59 | 0.42 | Kaptai Reservoir, Bangladesh |
| Njiru et al. [8] | 53.90 | 0.50 | - | 3.30 | - | 2.83 | 0.91 | 1.92 | 0.68 | Lake Victoria, Kenyan |
| Novaes and Carvalho [9] | 33.60 | 0.63 | - | 2.85 | - | 2.81 | 1.20 | 1.61 | 0.57 | Barra Bonita Reservoir, Brazil |
| El-Bokhty and El-Far [10] | 25.73 | 0.73 | - | - | 14.1 | 3.64 | 1.44 | 2.20 | 0.60 | River Nile, Aswan, Egypt |
| El-Kasheif et al. [11] | 37.27 | 0.29 | 0.090 | 2.61 | 14.2 | 1.15 | 0.65 | 0.49 | 0.43 | El-Bahr El-Faraouny Canal, Egypt |
| Yongo and Outa [12] | 46.24 | 0.69 | - | 3.14 | 20.3 | 2.18 | 1.14 | 1.05 | 0.46 | Lake Victoria, Kenya |
| Alemu et al. [13] | 36.23 | 0.33 | - | - | - | 1.06 | 0.67 | 0.39 | 0.38 | Lake Hawassa, Ethiopia |
| Shija et al. [15] | 55.00 | 0.37 | -0.467 | - | - | 1.51 | 0.79 | 0.72 | 0.48 | Lake Chamo, Ethiopia |
| Present study | 30.49 | 0.45 | -0.313 | 2.62 | 14.9 | 3.26 | 1.03 | 2.24 | 0.69 | Garmat Ali river |

The total mortality (Z), natural mortality (M), fishing mortality (F) rates and the exploitation rate (E) of *O. niloticus* comparing with those obtained by the various authors in different regions are given in Table 2. The values of total and natural mortality rates obtained here are within the range observed in other populations of *O. niloticus*, where the lowest values of Z and M were 1.06 and 0.67, respectively recorded by Alemu et al. [13] from Lake Hawassa, Ethiopia, and the highest values were 3.64 and 1.44, respectively obtained by El-Bokhty and El-Far [10] from River Nile at Aswan region, Egypt. On the other hand, the fishing mortality and the exploitation rates of *O. niloticus* attained in this study were close to those obtained by El-Bokhty and El-Far [10] for the fishing rate of *O. niloticus* from the Nile River at Aswan region, and Ahmed et al. [7] for the exploitation rate for the same species from Lake Victoria, Kenya, nevertheless both rates were higher than other estimates in Table 2. The optimum level of exploitation is 0.5 when fishing mortality is equal to natural

one [39]. Hence, the the exploitation rate (E) in the present study (0.69) study indicates that the species is under high level of fishing pressure.

Recruitment pattern of *O. niloticus* species in this study reveals that the major pulse takes place in June. A similar trend was also observed in the study of Ahmed et al. [7] for the species in Kaptai Reservoir, Bangladesh.

The plot of relative yield per recruit (Y/R) and biomass per recruit (B/R) against exploitation rate (E) for *O. niloticus* was done using the knife-edge selection procedure and the data of $L_c/L_\infty = 0.490$ and $M/K = 2.289$ to estimate the biological target reference points, $E_{0.1}$ and E_{max} [14]. The results of the analysis indicated that the present exploitation rate ($E_{present} = 0.69$) of *O. niloticus* was slightly lower than the optimum exploitation rate ($E_{0.1} = 0.707$) and considerably lower than the maximum one ($E_{max} = 0.824$) which indicates that the stock of *O. niloticus* is underexploited in the study river. These findings have been noticed for *O. niloticus* stocks by other authors in different regions. Ahmed et al. [7] found that the values of $E_{present}$ and E_{max} were 0.42 and 0.63, respectively in Kaptai Reservoir, Bangladesh. Novaes and Carvalho [9] pointed out that the values of $E_{present}$, $E_{0.1}$ and E_{max} were 0.570, 0.604 and 0.776, respectively in Barra Bonita Reservoir, Brazil. El-Bokhty and El-Far [10] stated that $E_{present} = 0.60$, $E_{0.1} = 0.757$ and $E_{max} = 0.877$ for the species in River Nile at Aswan region, Egypt. Also, El-Kasheif et al. [11] noted that the values of $E_{present}$, $E_{0.1}$ and E_{max} were 0.43, 0.51 and 0.64, respectively for the species in El-Bahr El-Faraouny Canal, Egypt. Mohamed and Abood [31] reported that the exploitation rates for *C. zillii* and *O. aureus* in the Shatt Al-Arab river were below the biological target reference points ($F_{0.1}$ and F_{max}), indicated that these species were also not overexploited.

Based on present results, the invasive *O. niloticus* stock was underexploited, since did not attain the maximum sustainable yield, as there was a large difference between the length at first capture (L_c) and the length at first maturity (L_m), where Mohamed and Al-Wan [57] found that the length at first maturity (L_m) of *O. niloticus* in Garmat Ali river ranged from 7.0 to 8.0 cm. Hence, 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.

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