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

Ayat N. Salman and Abdul-Razak M. Mohamed*

Department of Fisheries and Marine Resources, College of Agriculture University of Basrah, Iraq

*Corresponding author's email: abdul19532001 [AT] yahoo.com

DOI: https://doi.org/10.24203/ajas.v8i6.6397

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, $t_o=-0.313$ and Ǿ=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 (8-42ºC) but their natural temperature range is 13.5-33.0ºC 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 compiled 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 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 $L\infty$, 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 (Ø′) was calculated according to the formula of Pauly and Munro [37]: $Ø' = \log_{10}K + 2\log_{10}L\infty$.

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 $L\infty$ 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 26.3ºC:

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

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 ($L\infty$ 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 $L_c/L\infty$ 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.

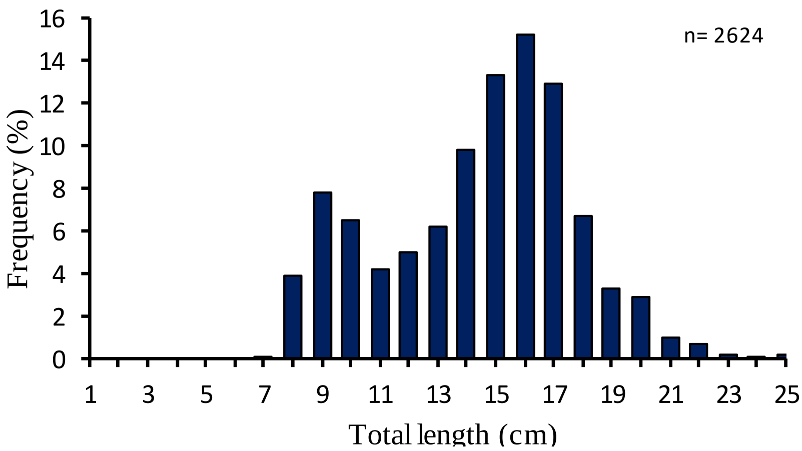

Figure 2: The overall length-frequency distribution of *O. niloticus*.

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.

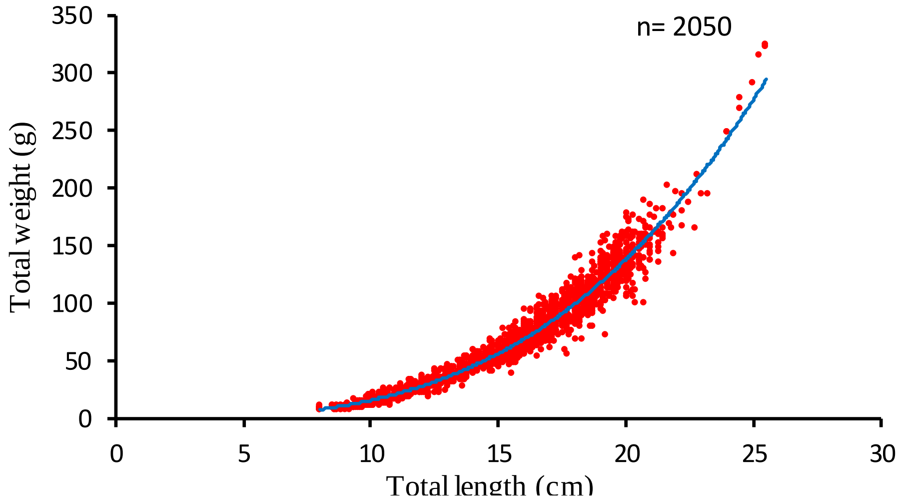

Figure 3: The length-weight relationship of *O. niloticus*.

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 ($L\infty$) 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_o was calculated as -0.313 years. The growth performance index (Ǿ) was estimated as 2.622.

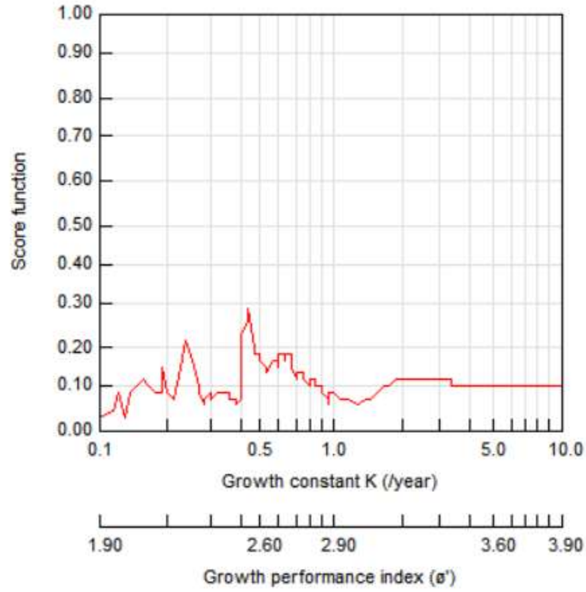

Figure 4: K-scan routines of *O. niloticus*.

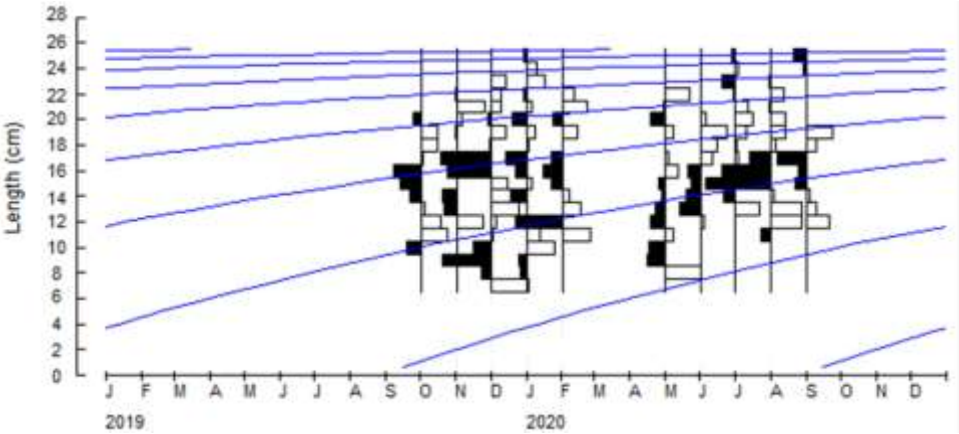

Figure 5: Restructured length-frequency distribution with growth curves superimposed using ELEFAN-1 for *O. niloticus*.

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.

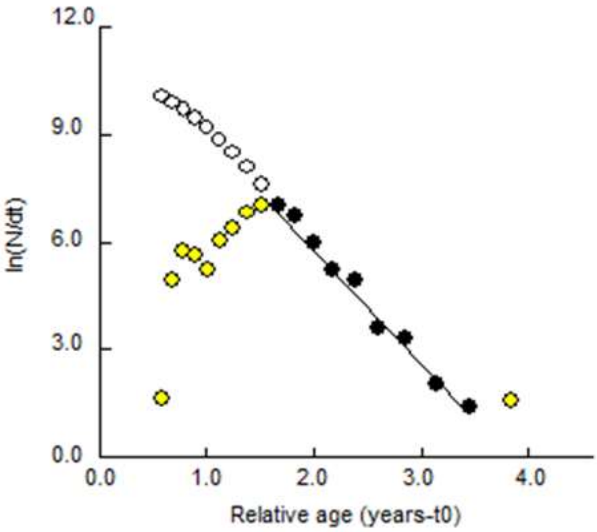

Figure 6: Length converted catch curves of *O. niloticus*.

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.

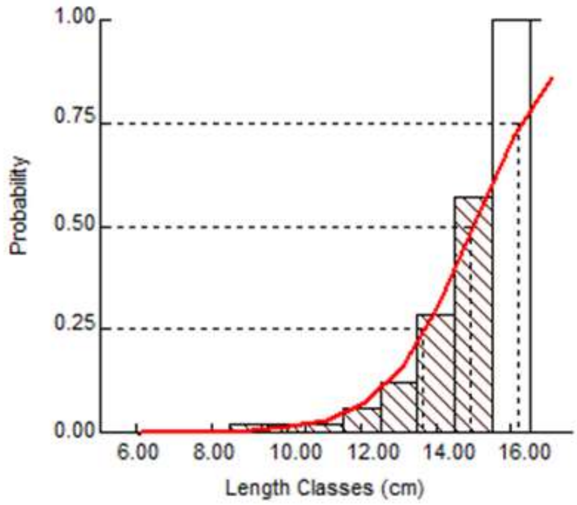

Figure 7: Probability of capture for *O. niloticus*.

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%).

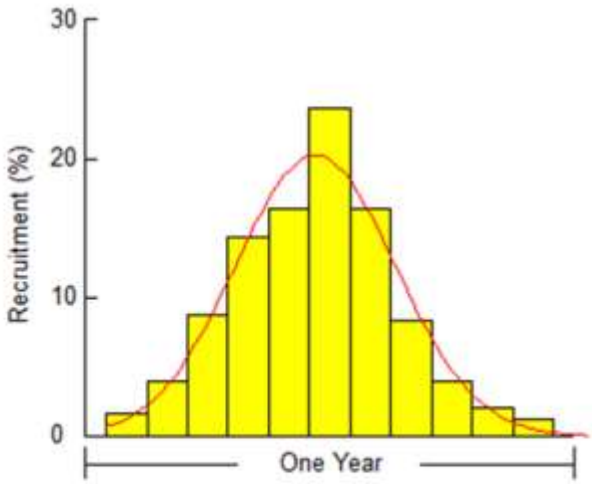

Figure 8: Recruitment pattern of *O. niloticus*.

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 $Lc/L\infty$ (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.

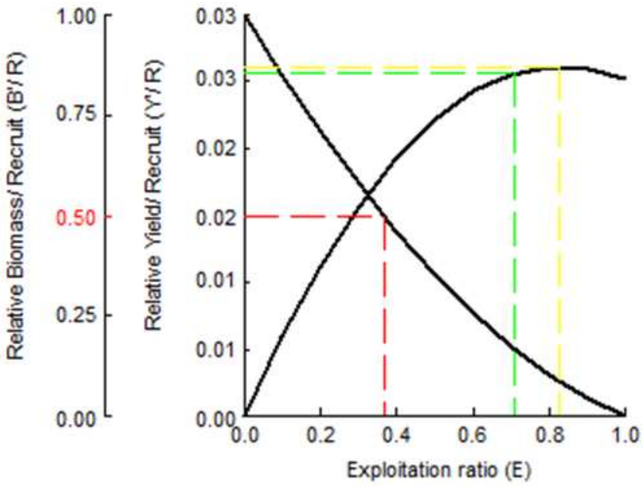

Figure 9: Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) analyses for *O. niloticus*.

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 Tinishu 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_o, Ǿ 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_o from -0.467 [15] to 0.09 [11]. The values of Ǿ 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_o**	**Ǿ**	**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 Al-Bakhti and Al-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 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.

5. REFERENCES

[1] Boyd EC. "Farm-level issues in aquaculture certification: tilapia". Report commissioned by WWF-US in 2004. Auburn University, Alabama, 2004.
[2] Lévêque C. 'Out of Africa: The success story of tilapias'. Environmental Biology of Fishes, vol 64, pp. 461-464, 2002.
[3] Zengeya TA, Robertson MP, Booth AJ, Chimimba CT. "Ecological niche modeling of the invasive potential of Nile tilapia *Oreochromis niloticus* in African river systems: concerns and implications for the conservation of indigenous congenerics". Biological Invasions, vol 15, pp. 1507-1521, 2013.
[4] FAO. "Cultured Aquatic Species Information Programme *Oreochromis niloticus* (Linnaeus, 1758)". http://www.fao.org/fishery/culturedspecies/*Oreochromis_niloticus*/en. October 2020 version.
[5] Snoeks J, Freyhof J, Geelhand D, Hughes A. "Oreochromis niloticus. The IUCN Red List of Threatened Species 2018". e.T166975A49922878. http://dx.doi.org/10.2305/IUCN. UK.2018.1.RLTS.T166975 A49922878.en.
[6] FAO. "GLOBEFISH Highlights-A quarterly update on world seafood Markets". January 2019 Issue. Food and Agriculture Organization of the United Nations, Rome, Italy, 2019.
[7] Ahmed KKU, Amin SMN, Haldar GC, Dewan S. "Population dynamics and stock assessment of *Oreochromis niloticus* (Linnaeus) in the Kaptai Reservoir, Bangladesh". Indian J. Fish., vol 50(1), pp. 47-52, 2003.
[8] Njiru M, Getabu A, Jembe T, Ngugi C, Owili M, van Knaap M. "Management of the Nile tilapia (*Oreochromis niloticus* (L.)) fishery in the Kenyan portion of Lake Victoria, in light of changes in its life history and ecology". Lakes and Reservoirs: Research and Management, vol 13, pp. 117-124, 2008.
[9] Novaes JLC, Carvalho ED. "Reproduction, food dynamics and exploitation level of *Oreochromis niloticus* (Perciformes: Cichlidae) from artisanal fisheries in Barra Bonita Reservoir, Brazil". Revista de biologia tropical, vol 60(2), pp. 721-734, 2012.
[10] El-Bokhty EEB, El-Far AM. "Evaluation of *Oreochromis niloticus* and *Tilapia zillii* fisheries at Aswan region, River Nile, Egypt". Egyptian Journal of Aquatic Biology and Fisheries, vol 18(3), pp. 79-89, 2014.
[11] El-Kasheif MA, Authman MMN, Al-Ghamdi FA, Ibrahim SA, El-Far AM. "Biological Aspects and Fisheries Management of Tilapia Fish *Oreochromis niloticus* (Linnaeus, 1758) in El-Bahr El-Faraouny Canal, Al- Minufiya Province, Egypt". Journal of Fisheries and Aquatic Science, vol 10(6), pp. 405-444, 2015.
[12] Yongo E, Outa N. "Growth and population parameters of Nile tilapia, *Oreochromis niloticus* (L.) in the open waters of Lake Victoria, Kenya". Lakes and Reservoirs: Research and Management, vol 21, pp. 375–379, 2016.
[13] Alemu Y, Snoeks J, Teklegiorgis Y, Nyssen J, Brendonck L. "Assessing sustainable fishing yields using length-based analytical models: A case study with Nile tilapia in Lake Hawassa (Ethiopia)". Journal of Fisheries and Livestock Production, vol 5(4), pp. 1-10, 2017.

[14] Ana Mehak YM, Mohsin M, Noman M, Nazir K. "Population dynamics of Nile Tilapia (*Oreochromis niloticus*) at Chashma Barrage, Pakistan". Indian Journal of Geo Marine Sciences, vol 46(01), pp. 206-210, 2017.
[15] Shija BS, Tesfaye G, Dadebo E. "Assessment of Maximum Sustainable Yield and Optimum Fishing Effort for the Nile Tilapia (*Oreochromis niloticus* L.) in Lake Chamo, Ethiopia". Journal of Agriculture and Environmental Sciences, vol 4(2), pp. 69-86, 2019.
[16] Al-Faisal AJ, Mutlak F.M. "First record of the Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758), from the Shatt Al-Arab River, Southern Iraq". Mesopotamia Journal of Marine Sciences, vol 29(1), pp. 45-50, 2014.
[17] Abulheni AKJ, Abbas LM. "First record of the Tilapia *Oreochromis niloticus* (Linnaeus,1758) in Euphrates River at Al-Hindia Barrier, Middle of Iraq". Journal of the University of Kerbala. Speciel issue, pp. 18-21, 2017.
[18] Khalifa SZ. "Ecological and biological of Nile tilapia *Oreochromis niloticus* and blue tilapia *Oreochromis aureus* from Tigris River, Southern Baghdad". MSc. Thesis. University of Diyala, Iraq. 123p, 2017.
[19] Mohamed ARM, Abood AN. "Compositional change in fish assemblage structure in Shatt Al-Arab River, Iraq". Asian Journal of Applied Sciences, vol 5(5), pp. 944-958, 2017.
[20] Mohamed ARM, Hussein SA, Lazem LF. Spatiotemporal variability of fish assemblage in the Shatt Al-Arab River, Iraq. Basrah Journal of Agricultural Sciences, vol 26(1), pp. 43-59, 2013.
[21] Mohamed ARM, Hameed EK. "Impacts of saltwater intrusion on the fish assemblage in the middle part of Shatt Al-Arab River, Iraq". Asian Journal of Applied Sciences, vol 7(5), pp. 577-586, 2019.
[22] Negaud KZ. "Some biological aspects of Nile tilapia Oreochromis niloticus L. in AL-Rumaitha district, Al-Muthanna province, southern Iraq". MSc. Thesis, University of Al-Muthanna, Iraq. 83p, 2019.
[23] AL-Shamary ACh. "Effect of alien species on assemblage fish in Shatt Al-Arab river and East Al-Hammar Marsh". Mesopotamia Environmental Journal, Special Issue A, pp. 18-32, 2016.
[24] Abdullah SA. "Diversity of fishes in the lower reaches of Tigris River, north east of Basrah province, Southern Iraq". Basrah Journal of Agricultural Sciences, vol 30(1), pp. 85-96, 2017.
[25] Abdullah AHJ, Abdullah SA, Al-Robayii OA. "Spatial and temporal pattern of sympatric fish assemblage in the Al-Sweib River South of Iraq". Proceedings of the 3rd Agricultural Scientific Conference 5-6 March 2018. The University of Kerbala, pp. 1-17, 2018.
[26] Abdullah SA, Abdullah AHJ, Ouda YW. "Diversity and status of fish fauna in the Al-Kahlaa River, in Missan Province-Iraq, with notes on environmental variables". EurAsian Journal of BioSciences, vol 13, pp. 1817-1824, 2019.
[27] Canonico GC, Artihington A, McCrary JK, Thieme ML. "The effects of introduced tilapias on native biodiversity". Aquatic Conservation: Marine and Freshwater Ecosystems, vol 15, pp. 463-483, 2005.
[28] Simoes Vitule JR, Freire CA, Simberloff D. "Introduction of non-native freshwater fish can certainly be bad. Fish and Fisheries, vol 10, pp. 98-108, 2009.
[29] Genner MJ, Connell E, Shechonge A, Smith A, Swanstrom J, Mzighani S, Mwijage A, Ngatunga BP, Turner GF. "Nile tilapia invades the Lake Malawi catchment". African Journal of Aquatic Science, vol 38, pp. 85-90, 2013.
[30] Vicente IST, Fonseca-Alves CE. "Impact of introduced Nile tilapia (*Oreochromis niloticus*) on non-native aquatic ecosystem". Pakistan Journal of Bioogical Sciences, vol 16(3), pp. 121-126, 2013.
[31] Mohamed ARM, Abood AN. "Population dynamics and management of two cichlid species in the Shatt Al-Arab River, Iraq". Journal of Applied and Natural Science, vol 12(2), pp. 261-269, 2020.
[32] Gayanilo FCJr, Sparre P, Pauly D. "FAO-ICLARM Stock Assessment Tools II (FiSAT II)". Revised version. User's guide. FAO Comp. Info. Ser. (Fisheries), vol 8, pp. 1-168, 2005.
[33] Le Cren ED. "The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*)". Journal Animal of Ecology, vol 20, pp. 201-219, 1951.
[34] Ricker WE. "Computation and interpretation of biological statistics of fish populations". Bull. Fish. Res. Bd. Canada, vol 191, pp. 1-382, 1975.
[35] Pauly D. "Some simple methods for assessment of tropical fish stocks. FAO Fish. Tech. Pap., 234: 52p, 1983.
[36] Sparre P, Venema SC. "Introduction to tropical fish stock assessment". Part 1. Manual. FAO fisheries technical paper. No. 306. 1, Rev. 2. FAO, Rome, Italy. 407 p, 1998.
[37] Pauly D, Munro JL. "Once more on the comparison of growth in fish and invertebrates". ICLARM Fishbyte, vol 2(1), pp. 21, 1984.
[38] Pauly D. "On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks". J. Cons. CIEM, vol 39(3), pp. 175-192, 1980.
[39] Gulland JA. "Fish resources of the Ocean". Fishing News Books, Surrey, London, England. 255p, 1971.
[40] Pauly D."A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates". *In*: Pauly D, Morgan GR. (eds.). Length-based Methods in Fisheries Research, 13. ICLARM, 1987.
[41] Beverton RJH, Holt SJ. "Manual of methods for fish stock assessment". Part II. Fish. Biol. Tech. Pap., vol 38, pp. 10-67, 1966.
[42] Pauly D, Soriano ML. "Some practical extensions to Beverton and Holt's relative yield-per-recruit model". *In*: Maclean JL, Dizon LB, Hosillo LV. (eds.). The First Asian Fisheries Forum, pp. 491-496, 1986.
[43] Cadima EL. "Fish stock assessment manual". FAO Fisheries Technical Paper. No. 393. Rome, FAO. 161p, 2003.

[44] Kebtieneh N, Alemu Y, Tesfa M. "Stock Assessment and Estimation of Maximum Sustainable Yield for Tilapia Stock (*Oreochromis niloticus*) in Lake Hawassa, Ethiopia". Agriculture, Forestry and Fisheries, vol 5(4), pp. 97-107, 2016.

[45] El-Bokhty EEB. "Assessment of family Cichlidae inhabiting Lake Manzala, Egypt". Egyptian Journal of Aquatic Biology and Fisheries, vol 10, pp. 85-106, 2006.

[46] Bwanika GN, Murie DJ, Chapman LJ. "Comparative age and growth of Nile tilapia (*Oreochromis niloticus* L.) in lakes Nabugabo and Wamala, Uganda". Hydrobiologia, vol 589, pp. 287-301, 2007.

[47] Mahmoud MH, Mazrouh MM. "Biology and fisheries management of tilapia species in Rosetta branch of the Nile River, Egypt". Egyptian Journal of Aquatic Research, vol 34(3), pp. 272–285, 2008.

[48] Shalloof KA, El-Far AM. "Age, growth and fishery biology of cichlid spp. In Abu-Zaabal Lakes, Egypt". Egyptian Journal Aquatic Biology and Fisheries, vol 13, pp. 101-116, 2009.

[49] Hirpo LA. "Reproductive biology of *Oreochromis niloticus* in Lake Beseka, Ethiopia". Journal of Cell and Animal Biology, vol 7(9), pp. 116-120, 2013.

[50] Hassan AA, El-Kasheif MA. "Age, growth and mortality of the cichlid fish *Oreochromis niloticus* (L.) from the River Nile at Beni Suef Governorate, Egypt". Egyptian Journal Aquatic Biology and Fisheries, vol 17(4), pp. 1-12, 2013.

[51] Mortuza MG, Al-Misned FA. "Length-weight Relationships, condition factor and sex-ratio of Nile Tilapia, *Oreochromis niloticus* in Wadi Hanifah, Riyadh, Saudi Arabia". World Journal of Zoology, vol 8(1), pp. 106-109, 2013.

[52] Kembenya EM, Ogellob EO, Githukiac CM, Aerad CN, Omondie R, Mungutif JM. "Seasonal changes of length-weight relationship and condition factor of five fish species in Lake Baringo, Kenya". International Journal of Sciences: Basic and Applied Research, vol 14(2), pp. 130-140, 2014.

[53] Shalloof KA, El-Far AM. "Length-weight relationship and condition factor of some fishes from the River Nile in Egypt with special reference to four tilapia species". Egyptian Journal of Aquatic Biology and Fisheries, vol 21(2), pp. 33-46, 2017.

[54] Teame T, Zebib H, Meresa, T. "Observations on the biology of Nile tilapia, *Oreochromis niloticus* L., in Tekeze Reservoir, Northern Ethiopia". International Journal of Fisheries and Aquaculture, vol 10(7), pp. 86-94, 2018.

[55] Enawgaw Y, Lemma B. "Seasonality in the diet composition and ontogenetic dietary shifts of (*Oreochromis niloticus* L.) (Pisces: Cichlidae) in Lake Tinishu Abaya, Ethiopia". International Journal of Fisheries and Aquatic Research, vol 3(1), pp. 49-59, 2018.

[56] Cuadrado JT, Lim DS, Alcontin RMS, Calang JL, Jumawan JC. "Species composition and length-weight relationship of twelve fish species in the two lakes of Esperanza, Agusan del Sur, Philippines". FishTaxa, vol 4(1), pp. 1-8, 2019.

[57] Mohamed ARM, Al-Wan SA. "Biological aspects of an invasive species of *Oreochromis niloticus* in the Garmat Ali River, Basrah, Iraq". Journal of Agriculture and Veterinary Science, vol 13(2), pp. 15-26, 2020.

[58] Nikolsky GV. "The ecology of fishes". Academic Press, London and New York, 352 p, 1963.

[59] Bwanika GN, Makanga B, Kizito Y, Chapman LJ, Balirwa J. "Observations on the biology of Nile tilapia, *Oreochromis niloticus* L., in two Ugandan crater lakes". African Journal of Ecology, vol 42, pp. 93–101, 2004.

[60] Riedel R, Caskey LM, Hurlbert SH. "Length-weight relations and growth rates of dominant fishes of the Salton Sea: implications for predation by fish-eating birds". Lake and Reservoir Management, vol 23, pp. 528-535, 2007.

[61] King MM. "Fisheries Biology, Assessment and Management". 2nd ed. Blackwell Publishing Ltd, 400p, 2007.

[62] Froese R, Tsikliras AC, Stergiou KI. "Editorial note on weight length relations of fishes". Acta Ichthyol Piscat, vol 41, pp. 261–263, 2011.

[63] Froese R. (2006). "Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations". Journal of Applied Ichthyology, vol 22(4), pp. 241-253.

[64] Santos AFG, Santos LN, Araujo FG. "Water level influences on body condition of *Geophagus brasiliensis* (Perciformes: Cichlidae) in a Brazilian oligotrophic reservoir". Neotropical Ichthyology, vol 2(3), pp. 151-156, 2004.

[65] Wootton RJ. "Growth: environmental effects". *In*: Farrell AP. (ed.). Encyclopedia of fish physiology: from genome to environment. Elsevier Science Publishing Co. Inc, USA, pp. 1629-1635, 2011.

[66] Panda D, Mohanty SK, Pattnaik AK, Das S, Karna SK. "Growth, mortality and stock status of mullets (Mugilidae) in Chilika Lake, India". Lakes and Reservoirs, vol 2018, pp. 1-13, 2018.