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Assessment of two cichlids stocks with virtual population analysis in Garmat Ali River, Basrah, Iraq

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Abstract

The study is an attempt to evaluate the population characteristics and virtual population analysis (VPA) of two invasive species (*Oreochromis niloticus* and *Oreochromis aureus*) using the FiSAT II software based on the data collected from the Garmat Ali River, Iraq. A total of 4391 individuals (2727 of *O. niloticus* and 1664 of *O. aureus*) were measured for length-frequency analysis from October 2019 to September 2020. Length-weight relationships were derived, indicating allometric growth for both species. The asymptotic length ($L\infty$) and growth rate constant (K) were estimated to be 30.5 cm and 0.45 for *O. niloticus* and 29.9 cm and 0.21 for *O. aureus*. The annual rates of fishing (F) and exploitation (E) for *O. niloticus* were found to be 2.24 and 0.69, respectively, and for *O. aureus* 0.48 and 0.43, respectively. The present exploitation rates (E) of both species were below the biological target reference points, $E_{0.1}$ and E_{max}, thus expressing a case of under-exploitation of both species. Besides, the result of the virtual population analysis (VPA) revealed that the majority of *O. niloticus* and *O. aureus* individuals were harvested at lengths 20 cm and 17 cm, respectively. Also, the lengths at first capture (L_{50}) for both species were considerably higher than their lengths at first maturity (L_m). Therefore, for management purposes, this study suggests that more yields can be obtained by increasing the fishing activities on these invasive species, such as increasing the number of fishing boats and decreasing the mesh size to decline its abundance in the long term.

Keywords: Cichlids; Stock analysis; Virtual population analysis; Garmat Ali River; Iraq

1. Introduction

The Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) and the blue tilapia, *Oreochromis aureus* (Steindachner, 1864) are members of the Cichlidae family. The family is native to Africa and the south-western Middle East and can be found today in other waters around the world inhabiting a variety of fresh and less commonly brackish water habitats, from shallow streams and ponds through the rivers, lakes and estuaries [1]. Fricke *et al*. [2] stated that this family comprised 251 genera, 2295 available species and 1731 valid species.

Cichlids have been widely introduced, either deliberately for aquaculture or accidentally through the aquarium trade and become the second most important fish in aquaculture after carps, the worldwide production exceeded 5.6 million tons during 2018 [3]. Conversely, Cichlids species are invasive fish to Iraqi waters, and early records show that *Coptodon zillii* caught from the Euphrates River, middle of Iraq during 2007, later other species, *O. aureus* and *O. niloticus* documented in the south of Iraq. Currently, these three species are well established and dominate the fish populations in various Iraqi waters [4-13].

Virtual population analysis (VPA) is a modelling technique commonly used in fisheries science for reconstructing the historical population structure of fish stock using the information on the deaths of individuals in each time step. The

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time steps are typically annual (though not necessarily) and the deaths are usually partitioned into mortality due to fishing and natural mortality [14]. Virtual population analysis of cichlids has been studied by some investigators in some reservoirs in the world using FiSAT II (FAO-ICLARM Stock Assessment Tools) software such as Ahmed *et al*. [15] in the Kaptai Reservoir, Bangladesh; Athukorala and Amarasinghe [16] in two reservoirs of the Walawe river basin, Sri Lanka and Amarasinghe *et al.* [17] in Minneriya, Udawalawe and Victoria Reservoirs, Sri Lanka.

However, there is no study on the virtual population analysis on cichlids species in Iraqi waters. Therefore, the present work covers growth, stock predictions and virtual population analysis of the *O. niloticus* and *O. aureus* populations in the Garmat Ali river, north of Basrah, to provide information for proper management of these cichlids species.

2. Material and methods

2.1. Study area

The Garmat Ali River is a waterway that connects the East Hammar marsh to the Shatt Al-Arab River, lies in the area between 30° 34- to 30° 35- N and 47°43- to 47° 46- E (Fig. 1). The river is affected by the tidal current of the Arabian Gulf through the Shatt Al-Arab River. Its length is about 6 km with a width of 280 m and a mean depth of 9 m. Monthly water temperatures for the river ranged from 13.4°C to 32.5°C, with a mean value was 26.3°C. The shoreline vegetation of the river is typically associated with characteristic emergent macrophytes comprising a majority of *Phragmites australis* and *Typha domingensis,* as well as floating species like *Ceratophyllum demersum.*

2.2. Fish sampling

A total of 2727 individuals of *O. niloticus* and 1664 individuals of *O. aureus* were collected monthly from two sites on the river, the first site is located near Al-Najeebia Bridge opposite the site of the Naval Academy and the second site is located at the upper river before its confluence with the East Hammar marsh (Fig. 1) during October 2019 to September 2020 [18]. Fish were caught by drifted gill nets (200-500 m length, with 15x35 mm mesh size), fixed gill nets (100-300 m length, with 15x35 mm, mesh size), cast net (9 m diameter, with 15x15 mm mesh size) and electro-fishing by generator engine (providing 300-400V and 10A). After capture, the fish samples were then preserved in a plastic carrier containing enough ice and taken to the laboratory for further analysis.

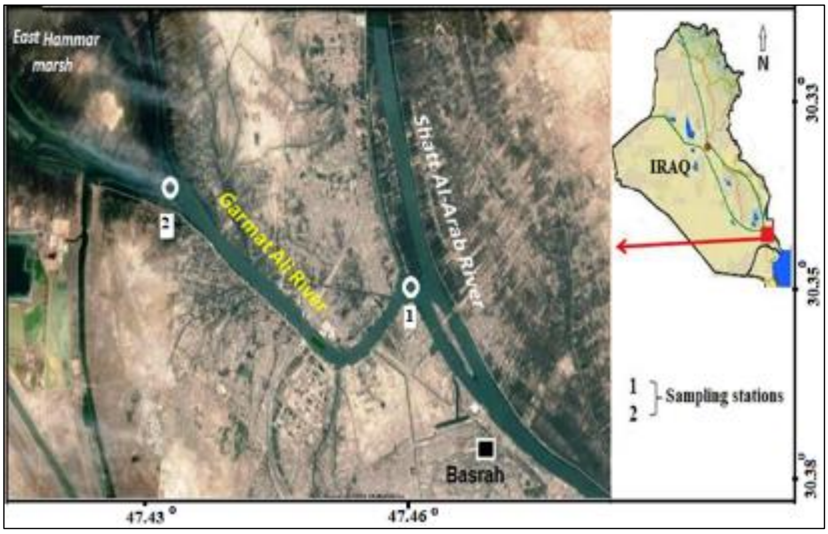

Figure 1 Map of Shatt Al-Arab with locations of study sites

2.3. Analytical analysis

At the laboratory, the fish were individually weighed using the electronic weighing balance to the nearest 0.1g, with the total lengths measured to the nearest 0.1 cm using the measuring board. The monthly samples of length measurements from the two stations were grouped into 1-cm intervals, sequentially arranged according to a time series of 12 months. The data were analyzed using FiSAT II software (FAO-ICLARM Stock Assessment Tools, ver. 1.2.2) [19]. The total length (L) relationship to the weight (W) for the two species was established using the power equation [20]: $W = a * L^b$, where a the intercept and b is the slope (growth coefficient). Furthermore, the b-value for each species was tested by t-test to verify if it was significantly different from isometric growth [21].

The parameters of the von Bertalanffy Growth function (VBGF), asymptotic length ($L\infty$) and growth coefficient (K) were estimated using the ELEFAN-I (Electronic LEngth Frequency ANalysis) routine of the FiSAT II software, which allows the fitted curve through the maximum number of peaks of the length-frequency distribution. With the help of the goodness of fit value (R_n), growth constant (K) and asymptotic length ($L\infty$) were estimated [22, 23].

The instantaneous total annual mortality rate (Z) was estimated using the length-converted catch curve analysis method of Pauly [22] incorporating in FiSAT II program 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 natural mortality (M) was estimated using the empirical relationship derived by Pauly [24] where the mean annual water temperature was set at 26.3°C:

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

Thus, the fishing mortality rate (F) was calculated from the relation F= (Z-M).

The relative yield-per-recruit (Y'/R) analysis was carried out using the knife-edge analysis of Beverton and Holt [25] as modified by Pauly and Soriano [26], and the data of $L_c/L\infty$ and M/K values as described in the FiSAT software package to estimate the biological target reference points, $E_{0.1}$ and E_{max} [27].

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 [28] and incorporated in the FiSAT package to determine the array of (F) for each length class. The input parameters used were $L\infty$, K, M, F and constants of length-weight relationship (a and b) for *O. niloticus* and *O. aureus* were used as inputs to VPA analysis for each species.

The initial step is to estimate the terminal population (N_t) given the inputs, from:

$$N_t = C_t \cdot (M + F_t)/F_t,$$

where C_t is the terminal catch (i.e., the catch taken from the largest length class).

Then, starting from N_t, successive values of F are estimated, by iteratively solving:

$$C_i = N_{i+\Delta t} \cdot (F_i/Z_i) \cdot (\exp(Z_i \cdot \Delta t_i)-1),$$

where $\Delta t_i = (t_i+1 - t_i)$, and $t_i = t_o - (1/K) \cdot \ln(1-(L_i/L_\infty))$, and where population sizes (N_i) are computed from:

$$N_i = N_{i+\Delta t} \cdot \exp(Z_i)$$

The last two equations are used alternatively, until the population sizes and fishing mortality for all length groups have been computed [19]. An F-array representing the fishing mortality for each length group, the reconstructed population (in numbers), and the mean stock biomass by length class were made using FiSAT II. The results of the VPA analysis were the biomass (tons), the yield (tons), total and fishing mortality and exploitation ratios.

3. Results and discussion

3.1. Growth

The length-weight data including 2727 specimens of *O. niloticus* and 1664 specimens of *O. aureus* from the Garmat Ali River during the period from October 2019 to September 2020 were analyzed and their descriptive statistics are presented in Table 1. The length and weight of O. *niloticus* was 7.0 to 25.0 cm and 8.0 to 325.0 g, respectively, while the length of *O. aureus* ranged between 7.5 and 26.3 cm and their weight varied between 6.0 to 356.0 g. The t-test revealed that the regression slopes (b) in the length-weight relationships for both species were significantly different from value 3 (t= 9.02, P<0.05 for *O. niloticus* and t= 4.97, P<0.05 for *O. aureus* indicated positive allometric growth for both species.

The outputs from the ELEFAN I and length-converted catch curve routines in FiSAT II software for *O. niloticus* and *O. aureus* in the studied river are summarized in Table 2. The growth curves of both species superimposed over the restructured length-frequency distributions through the ELEFAN I routine are presented in Figure 2. The obtained growth parameters were $L\infty$= 34.65 cm and K= 0.83 for *O. niloticus*, and for *O. aureus* were $L\infty$ = 19.43 cm and K= 1.4 (Table 2).

Table 1 The ranges for length and weight of *O. niloticus* and *O. aureus* in the Garmat Ali river.

Species	N	Length range (cm)	Mean length (±SD)	Weight range (g)	Mean weight (±SD)	Length-weight relationship		
						a	b	r^2
O. niloticus	2727	7.0-25.0	15.9 (±3.2)	8-325	76.9 (±43.1)	0.012	3.109	0.969
O. aureus	1664	7.5-26.3	14.0 (±3.2)	6-356	57.7 (±35.7)	0.015	3.075	0.963

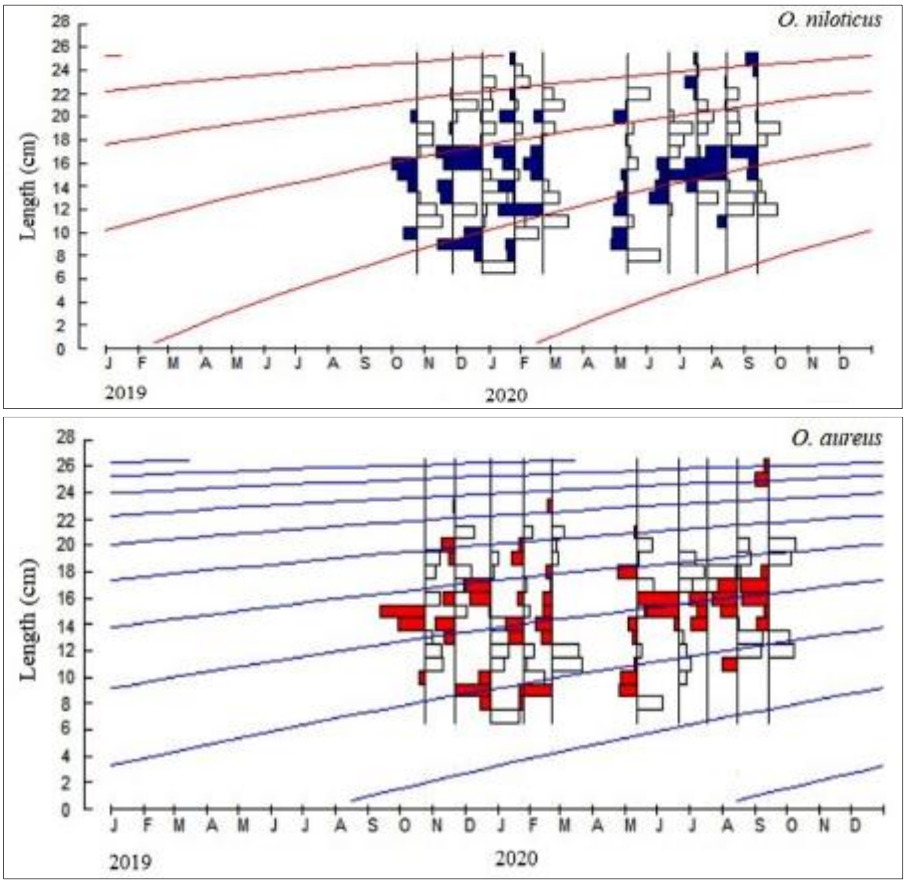

Figure 2 Growth curves of *O. niloticus* and *O. aureus* from the Garmat Ali river, by ELEFAN I superimposed on the length-frequency distribution data.

3.2. Stock predictions

The values for the rates of total mortality (Z), natural mortality (M) and fishing mortality (F) for *O. niloticus* were estimated to be 2.24, 1.03 and 2.24, respectively, while for *O. aureus* were 0.48, 0.61 and 0.48, respectively (Table 2). Moreover, the estimated values of the biological target reference points ($E_{0.1}$ and E_{max}) for *O. niloticus* were 0.707 and 0.824, respectively, and for *O. aureus* were 0.706 and 0.877, respectively. The present exploitation rates (E) are lower than the biological target reference points for both species.

Table 2 Estimates of parameters of growth, mortality and exploitation of *O. niloticus* and *O. aureus* in the studied river.

Population parameters	*O. niloticus*	*O. aureus*
Asymptotic length ($L\infty$, cm)	30.5	29.9
Growth coefficient (K)	0.45	0.21
The goodness of fit (R_n)	0.225	0.204

Total mortality rate (Z)	3.26	1.09
Natural mortality rate (M)	1.03	0.61
Fishing mortality rate (F)	2.24	0.48
Present exploitation rate ($E_{present}$)	0.69	0.43
Biological target reference point ($E_{0.1}$)	0.707	0.706
Biological target reference point (E_{max})	0.824	0.877

3.3. Virtual population analysis

Table 3 demonstrates the results of the virtual population analysis (VPA) of *O. niloticus* and *O. aureus.* It is clear from the table that the catches of both species occurred from size 7 cm and peaked at 16 cm. The recruitments of both species into the fishery were estimated at 8188.3 and 5180.0, respectively, then both populations decreased with the increased length classes.

The length groups from 16-22 cm of *O. niloticus* were more exploited in the fishery, whereas *O. aureus* was 16-19 cm. However, the length group 20 cm of *O. niloticus* was more vulnerable to fishing (2.595/y), whereas for *O. aureus* was 17 cm (1.495/y) according to VPA analysis, followed by length groups 17 cm (2.521/y) and 18 cm (2.159/y) for *O. niloticus,* and for *O. aureus* were 16 cm (1.400/y) and 18 cm (1.353/y). The average value of fishing mortality of *O. niloticus* was 1.189/y that was lower than the value estimated by catch-curve (2.24/y), whereas for *O. aureus* was 0.533, and this was slightly high than that estimated by catch-curve (0.48/y) for the species.

The maximum steady-state biomass of *O. niloticus* happened in length groups 14-15 cm (0.02 ton), whereas *O. aureus* occurred in length groups 12-15 cm (0.02 ton).

Figure 3 explains the results of the virtual population analysis (VPA) of *O. niloticus* and *O. aureus* in the present study about the natural losses, survivability and fishing mortality. The natural losses and survivability of the fish populations decreased with an increase in length and fishing mortality for both species. Also, it can be seen that the fishing mortality values of both species were not consistent. The highest values of fishing mortality were 2.595 for *O. niloticus* at length 20 cm and 1.495 for *O. aureus* at length 17 cm, after which there was a gradual decline in fishing mortality values for both species.

4. Discussion

Jennings *et al.* [29] stated that the assessment of fish population is essential to meet one of the main objectives of fishery science, that of maximizing yield to fisheries while safeguarding the long-term viability of populations and ecosystem. In the present study, both tilapia species showed positive allometric growth (b>3), i.e. this type of growth indicates that the fish becomes relatively stouter or deeper-bodied as it increases in length [30]. This pattern was reported for *O. niloticus* by Mortuza and Al-Misned [31], Kembenya *et al.* [32], Shalloof and El-Far [33], Cuadrado *et al.* [34], Negaud [13], and Mohamed and Al-Wan [35] from various water bodies in the world. However, some authors reported negative allometric growth for this species in other waters, such as Novaes and Carvalho [36], Hassan and El-Kasheif [37], Khalifa [38], Teame *et al.* [39], and Enawgaw and Lemma [40]. Mehanna [41] stated that the growth of *O. aureus* in Wadi El-Raiyan Lakes, Egypt was also positive allometric growth. Conversely, other studies found to be negative allometric as reported in the Infiernillo Reservoir, Mexico [42], in the Rosetta branch of the Nile River, Egypt [43], in the Aguamilpa Reservoir, Mexico [44], and the Nozha Hydrodrome, Egypt [45]. The difference in growth patterns is affected by several factors, including differences in geographical location, season, sex, stage of fish maturity, food availability, stomach fullness, health, stress and sampling methodology [21, 46, 34, 47].

The difference in the growth of the same species in different geographic locations is caused by several factors, including differences in habitat, environmental conditions, availability of food, metabolic activity, reproductive activity, the genetic constitution of the individual, sizes of fish, fishing pressure and sampling method [23, 52-53].

Virtual population analysis (VPA) is virtual in the sense that the population size is not observed or measured directly but is inferred or back-calculated to have been a certain size in the past to support the observed fish catches and an assumed death rate owing to non-fishery related causes [54]. The rates of fishing mortality (F) and the exploitation (E) for *O. niloticus* were higher than that observed for *O. aureus* in this study, and E of *O. niloticus* passed the optimum exploitation, which tends to be over-exploited according to Gulland [55] suggestion, the optimum exploitation rate is 0.5. The exploitation (E) of *O. niloticus* was close to that obtained of the species by Njiru *et al*. [56] from Lake Victoria, Kenyan (E= 0.68), and were higher than that observed for this species in other waters, such as Ahmed *et al*. [15], El-Kasheif *et al*. [49], Yongo and Outa [50] and Shija *et al.* [51]. On the other hand, the value of the exploitation rate (E) of *O. aureus* was close to that reported for the species from Lake Victoria, Kenyan by Mahmoud *et al.* [45], and was lower than those recorded for the species in some waters such as 0.85 in the Wadi El-Raiyan Lakes, Egypt [41], 0.61 in the Rosetta branch of the Nile River, Egypt [43] and 0.57 in Shatt Al-Arab River, Iraq [7].

Table 3 The outputs from the virtual population analysis of *O. niloticus* and *O. aureus*

Length class (cm)	Catch (numbers)		Population (N)		Fishing mortality (F)		Biomass (tons)	
	O. niloticus	*O. aureus*	*O. niloticus*	*O. aureus*	*O. niloticus*	*O. aureus*	*O. niloticus*	*O. aureus*
7	4	1	8188.3	5180.0	0.005	0.001	0	0.01
8	105	74	7422.9	4654.6	0.151	0.093	0.01	0.01
9	213	144	6603.6	4093.1	0.334	0.198	0.01	0.01
10	178	120	5733.3	3505.6	0.307	0.184	0.01	0.01
11	110	75	4957.9	2987.6	0.208	0.128	0.01	0.01
12	156	60	4303.8	2554.9	0.326	0.114	0.01	0.02
13	168	127	3655.1	2172.8	0.395	0.274	0.01	0.02
14	264	223	3048.5	1762.2	0.720	0.582	0.02	0.02
15	363	242	2406.6	1305.1	1.228	0.833	0.02	0.02
16	410	271	1739.1	885.6	1.904	1.400	0.01	0.01
17	349	169	1107.3	496.4	2.521	1.495	0.01	0.01
18	181	86	615.7	258.3	2.159	1.353	0.01	0.01
19	89	40	348.4	133.4	1.694	1.099	0.01	0
20	79	18	205.2	71.2	2.595	0.824	0	0
21	26	6	94.9	39.9	1.554	0.418	0	0
22	19	3	51.7	25.1	2.036	0.294	0	0
23	6	2	23.0	15.9	1.193	0.278	0	0
24	3	0	11.9	9.5	1.023	0.000	0	0
25	4	2	5.8	6.2	2.240	0.621	0	0
26		1		2.3		0.479		0
Mean						0.533		

The present exploitation rates (E) of both species in the present study were lower than the biological target reference points ($E_{0.1}$ and E_{max}), which indicates that the stocks are underexploited in the study river. Moreover, the result of the virtual population analysis (VPA) revealed that the majority of *O. niloticus* and *O. aureus* individuals were harvested at lengths 20 cm and 17 cm, respectively. Also, the estimated values for the length at first capture (L_{50}) of *O. niloticus* and *O. aureus* in the same river (14.9 and 13.9 cm, respectively) [57, 18] were greater than the lengths at first maturity (L_m) of *O. aureus*, 6.6-9.2 cm and *O. niloticus*, 7.0-8.0 cm [58, 35]. The occurrence of such a situation suggests that individuals of the species get the chance to join the stock before becoming vulnerable to capture by the available fishing gear. These would enable more females to participate in reproductive activity and allow the young recruits to grow and reproduce to ensure resource availability and sustainability [59].

Simoes Vitule *et al.* [60] indicated 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. King [61] stated that the **o**verall purpose of fisheries science is to provide decision-makers with advice on the relative merits of alternative management, and this advice may include predictions of the reaction of a stock and fishers to varying levels of fishing effort and, conventionally, include an estimate of the level of fishing effort required to obtain the maximum weight or yield that may be taken from stock on a sustainable basis. Since both species are exotic to the Iraqi waters, conservation measures to protect these species, such as the temporary prohibition of fishing, prohibition of fishing gear, controls of fish size caught and control of fishing effort, are not recommended for these waters. However, the impacts of cichlids introduced on native fish and their habitats were well documented [19]. Further, the cichlids are less desired as food by Iraqi people compared to exotic and indigenous cyprinids. For management purposes, more yields could be obtained by increasing the fishing activities on these species.

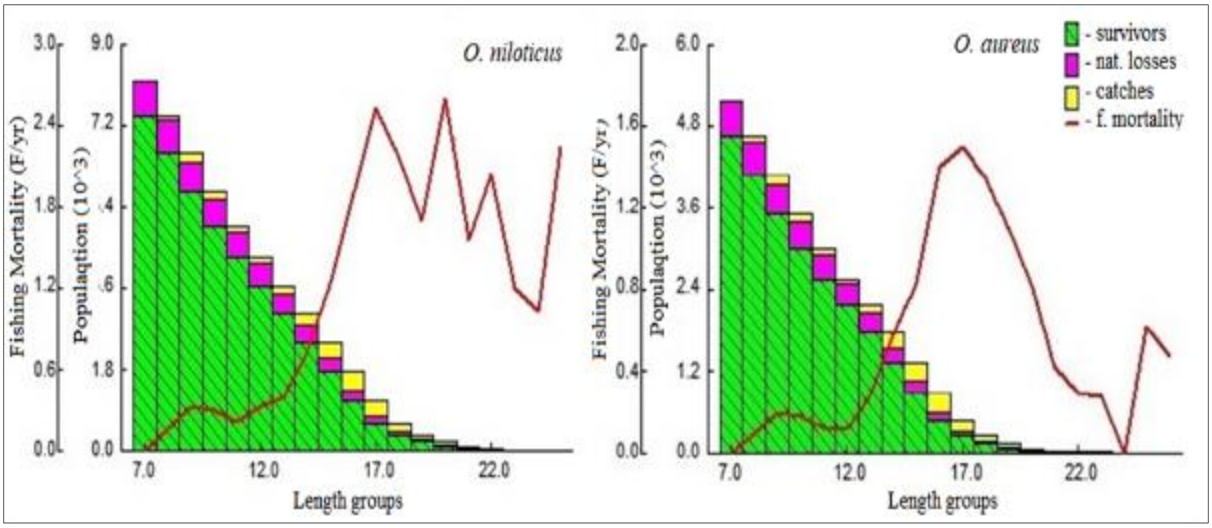

Figure 3 Length-structured virtual population analysis of *O. niloticus* and *O. aureus*

The analysis of growth parameters revealed that the asymptote length of *O. niloticus* (L∞= 30.5 cm) was slightly longer than that of *O. aureus* (L∞= 29.9 cm). The growth of *O. niloticus* in the present study was better than that documented for the species (L∞= 25.7 cm) by El-Bokhty and El-Far [48] in the River Nile, Aswan, Egypt, while was lower than those reported by other authors [15, 49-51]. Also, the asymptotic length (L∞) for *O. aureus* in this study was better than those recorded for the species in some waters such as 27.2 cm in the Wadi El-Raiyan Lakes, Egypt [41], 26.4 cm in the Rosetta branch of the Nile River, Egypt [43] and 27.8 cm in Shatt Al-Arab River, Iraq [7], whereas lower than the values reported by Messina *et al*. [44] in Aguamilpa Reservoir, Mexico and Mahmoud *et al*. [45] in Nozha Hydrodrome, Egypt.

5. Conclusion

The study concludes that more yields could be obtained by a reasonable decrease in the size of the first capture and increasing the fishing activities on these invasive species, such as increasing the number of fishing boats and decreasing the mesh size to decline its abundance in the long term.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest to be declared.

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