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Growth, Fishing Mortality and Exploitation Rates of *Oreochromis niloticus* and *Oreochromis aureus* Caught by Trammel Nets from El-Salam Canal, Egypt

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ABSTRACT

This preliminary study is the first concerning the age, growth, fishing, mortality, and exploitation rates of two tilapia fish (*Oreochromis niloticus* and *Oreochromis aureus*) caught by trammel nets from El-Salam Canal. Analysis of the length-frequency data of collected fish using the FiSAT program revealed von Bertalanffy's growth curve indicators as L_∞ = 24.86 cm, k = 1.3 year^{-1} for *O. niloticus* and L∞ = 19.14 cm, k = 1.9 year^{-1} for *O. aureus*. The longevity (maximum age) reached by *O. niloticus* was 4 years and for *O. aureus* was 3 years as revealed by Bhattacharya analysis. The lengths at first capture (L_c) of *O. niloticus* and *O. aureus* were 9.94 and 10.82cm, respectively. The total, natural and fishing mortality rates for *O. niloticus* were Z= 4.92 y^{-1}, M=2.02 y^{-1} and F= 2.9 y^{-1}, and those for *O. aureus* were Z= 5.99 y^{-1}, M=2.78 y^{-1} and F= 3.21 y^{-1}. The estimated values of exploitation ratios (E) were 0.59 and 0.54 for *O. niloticus* and *O. aureus*, respectively. Based on the optimal exploitation value (0.5), the results indicate that both species are considered to be over-exploited at El-Salam Canal, and the illegal fishing gear should be banned. In addition, more investigations should be carried out on other fishing gear to understand the real situation of tilapia stock in the canal.

INTRODUCTION

El-Salam Canal is one of the major agricultural land reclamation projects in Egypt, which aimed to develop the Sinai lands. It brings the Nile water to the deserts of north Sinai.

The trammel is one of the most important and widely used artisanal fisheries in Egypt and the whole world. These nets are similar to those used in Lake Manzala, and for detailed technical features of trammels, it will be useful to refer to **El-Bokhty (2017)**. Because of the nature of its construction, trammel nets are generally considered to be less size selective than gill nets, Therefore, a trammel net is able to catch both small and large-sized fish, thus the catching efficiency is relatively higher than gillnets **(Koike & Matuda, 1988; FAO, 2000; Fabi *et al*., 2002)**.

The common name for a species of cichlid fish native to Africa is tilapia. Three significant genera, *Oreochromis, Sarotherodon* and *Tilapia*, make up the group. More than 70 species of tilapia are found in the genus **(Meyer, 2002)**; it may now be found in many other waters across the world, but it was originally discovered in Africa and parts of the Middle East **(Mahmoud & Mazrouh, 2008)**. In Egypt, cichlids are found in the Nile River and its tributaries, the Delta lakes and Lake

Nasser in addition to inland waters. Thus, it is among Egypt's most important freshwater fisheries **(Mehanna, 2004)**. The Nile tilapia *Oreochromis niloticus* and the blue tilapia, *Oreochromis aureus* are the two most important species of cichlids in Egypt, along with two other species, *Sarotherodon galilaeus* and *Coptodon zillii*.

Age is an essential indicator in fish demography since it serves as the basis for the evaluation of growth and mortality rates as well as population productivity **(Campana, 2001)**. Upon using data from age-based stock assessment models, the best management practices are developed. Only when the relationship between length and age is known can important population statistics such as natural and fishing mortality, age composition of the exploited population, and age at first maturity, stock age structure, and recruitment success be calculated (**Stevenson & Campana, 1992)**.

Due to the importance of *O. niloticus* and *O. aureuss* fish in the Egyptian inland waters, many studies were designed on their biology and fisheries in different Egyptian water bodies, such as the studies of **Talaat (1979)**, **Shalloof (1991)**, **El Shazly (1993)**, **Bakhoum and Abdallah (2002)**, **Mehanna (2004)**, **Mehanna (2005)**, **El-Bokhty (2006)**, **Mahmoud and Mazrouh (2008)**, **Mohammed *et al*. (2009)**, **Shalloof and El- Far (2009)**, **El-Bokhty (2010)**, **Al-Sayes *et al*. (2012)**, **El-Bokhty *et al*. (2013)**, **Hassan and El-Kasheif (2013)**, **Mahmoud *et al*. (2013)**, **El-Bokhty and El-Far (2014 a, b)**, **Khallaf *et al*. (2020)**, **Mehanna *et al*. (2020)** and **El-Bokhty and Fetouh (2023)**.

In this context, this study's objective was to estimate the effect of using trammel nets on growth parameters, mortality rates and exploitation coefficients for the two tilapia species (*O. niloticus* and *O. aureus*) prevailing the catch of El-Salam Canal.

MATERIALS AND METHODS

Area of study

El-Salam Canal (Fig. 1) begins at 210 kilometers on the Damietta branch of the River Nile and flows southeast for approximately 89.4 kilometers. Then, it uses a siphon to cross the Suez Canal and arrives at the peninsula in north Sinai that stretches 175 kilometers eastward (**Othman *et al*., 2012**).

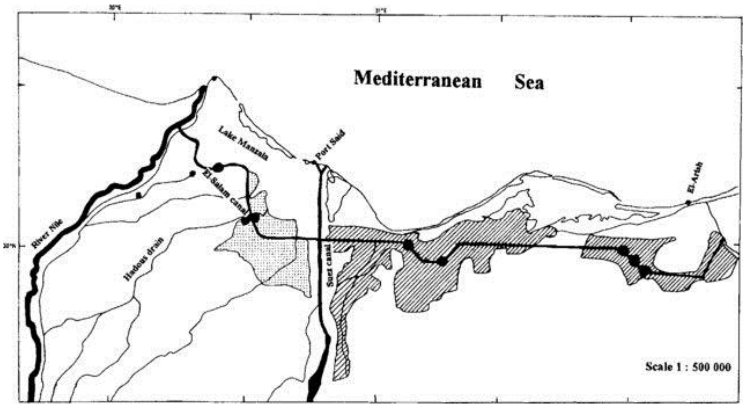

Fig. 1. Map showing the El-Salam Canal (ca. 88 km between Damietta branch of the Nile and the Suez Canal) **(**after **Serag & Khedr, 2001)**

Data and samples collection

Fish samples were collected from trammel nets used in El-Salam Canal during 2018. Fish were categorized to different species, and for each fish, the length of fish was measured with millimetre scale to the nearest millimetre.

Data analysis

The "FiSAT" software program's suitable routines and subroutines were applied to evaluate the length frequency distributions **(Gayanilo *et al*., 1997)**. An estimate of the asymptotic length (L_∞) and the growth coefficient (K) were obtained by the method of **Wetherall (1986)**. The parameters were then used as seed values in ELEFAN I routine **(Pauly, 1984a, b)** for estimating the best combination of L_∞ and K. The Phi-prime index Φ **(Munro & Pauly, 1983; Moreau *et al*., 1986)** for the species concerned was used to estimate the growth performance index as $\Phi = \log K + 2 \log L_\infty$. Zero age length ($to$) is estimated from **Pauly's (1979)** formula; $\text{Log}(-to) = -0.392 - 0.275 Log L\infty - 1.0381K$.

The instantaneous rate of total mortality (Z) was derived from the length converted catch curve method described by **Pauly (1983)**. The instantaneous rate of natural mortality (M) was computed from the empirical equation of **Pauly (1980)** considering the mean annual water temperature 22.5°C **(Mehanna, 2022)**. The instantaneous rate of fishing mortality (F) was extracted as F= Z–M. The exploitation rate was calculated as E = F/Z. The probabilities of length at first capture (L_c) was determined backward to the extrapolation of the linear length-converted catch curve according to **Pauly (1984a, b)**. Relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' were estimated using **Beverton and Holt (1966)** model as follows:

(Y/R)'= EUM/K [1-(3U/1+M)+(3U2/1+2M) – (U3/1+3M).

(B/R)'=(Y/R)' / F

RESULTS

Growth parameters

The length range of *O. niloticus* varied between a minimum of 9.5 and a maximum of 21.5cm. While, that of *O. aureus* ranged from 9.5 to 18.5cm. The age-length key obtained by the Bhattacharya decomposition method was adjusted by the NORMSEP program (FISAT II) via successive iterations (Table 1, Fig. 2). The longevity of *O. niloticus* and *O. aureus* in the present study were 4 and 3 years, respectively. This indicates that the maximum growth of two species was in the first year of life.

For *O. niloticus*, the Powell-Wetherall method **(Sparre & Venema, 1996)** provides a L_∞ of the order of 24.86cm. This L_∞ value is incorporated into the K-Scan Label of the ELEFAN I program to estimate a corresponding K- value based on the highest Rn score (ESP/ASP) **(Gayanilo *et al*., 2005)**. The program provides a value of K= 1.3/year. While, the values of L_∞, and K for *O. aureus* were 19.14cm and 1.9/y, respectively (Fig. 3).

Table 1. Mean age length-components as identified by Bhattacharya analysis for *O. niloticus* and *O. aureus* caught by trammel net from El-Salam Canal

Age group	**1**	**2**	**3**	**4**
Oreochromis niloticus				
Annual pooled	11.53	14.39	18.8	21.44
(S.D.)	0.84	1.53	1.79	2.17
(S.I.)		2.08	1.91*	2.05
Oreochromis aureus				
Annual pooled	11.63	13.35	15.03	
(S.D.)	0.73	1.01	1.03	
(S.I.)		2.00	1.95*	
Note: S. D.= Standard Deviation & S. I*. = Separation Index > or =2				

O. niloticus *O. aureus*

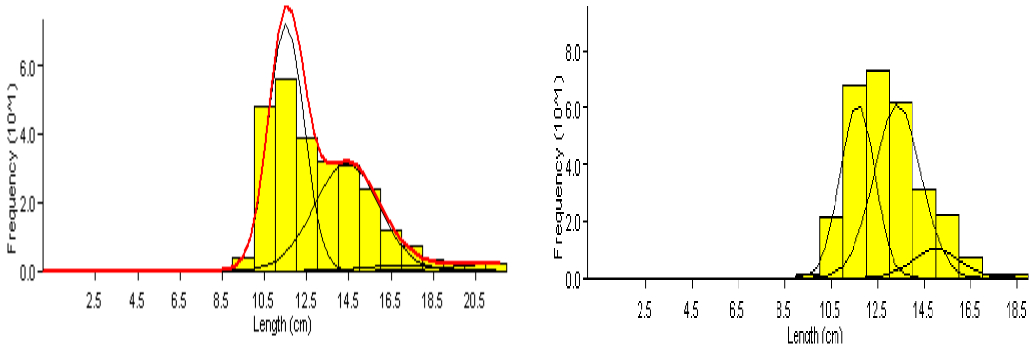

Fig. 2. Mean age cohorts of *O. niloticus* and *O. aureus* obtained by Bhattacharya method

O. niloticus *O. aureus*

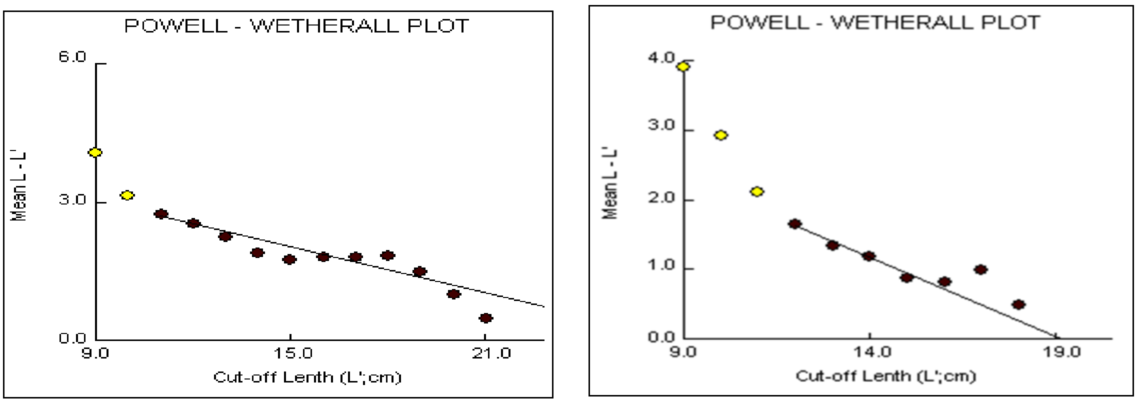

Fig. 3. Determination of L∞ and Z/K by the Powell-Wetherall method for *O. niloticus* and *O. aureus* caught by trammel net from El-Salam Canal

Growth performance index

The growth performance index (Φ) of *Oreochromis niloticus* was estimated with a value of 2.91. This growth index is considered as the best and highest value than that recorded by **El-Bokhty (2006)** at Lake Manzalah. This may be related to the high adaptability of *O. niloticus* to tolerate a wide range of pH, low levels of dissolved oxygen and feeds on a variety of food items **(Njiru, 1999)**. Φ value for *O. aureus* was calculated as 2.84, indicating a good growing rate of this species. Howbeit, similar results were achieved by **Abdel-Aziz *et al.* (1990)** (2.55) at Lake Edku and is considered higher than that recorded (2.44) at Lake Manzalah by **El-Bokhty (2006)**. This difference is perhaps a manifestation of the observations that similar species may experience different growth rates in different habitats **(Lowe-McConnell, 1982)**.

Mortality estimation. The different mortality coefficients of *O. niloticus* and *O. aurues* caught by trammel net from El-Salam Canal are showed in Fig. (4). Using the length converted catch curve, the annual instantaneous rate of total mortality (Z) was estimated at 4.92 y^{-1} and 5.99 y^{-1} for *O. niloticus* and *O. aurues*, respectively. The solid line shows the regression equation fitting to the length-transformed catch curve data. The natural mortality (M) derived from the Pauly's empirical formula was 2.02 for *O. niloticus*; while for *O. aurues*, it was 2.78 considering the mean annual temperature as 22.5^{o}C . The calculated fishing mortality (F) was 2.9 and 3.21 for *O. niloticus* and *O. aurues*, respectively.

Exploitation ratio. In the present study, the estimated values of exploitation ratio (E) was 0.59 for *O. niloticus* and that of *O. aurues* was 0.54 **(Figure 4)**.

Table (2) shows the Von Bertalanffy's growth parameters (L_∞, K and t_o), the instantaneous total, natural and fishing mortality rate and the current exploitation rate (E) of *O. niloticus* and *O. aureus* caught by trammel net from El-Salam Canal.

O. niloticus *O. aureus*

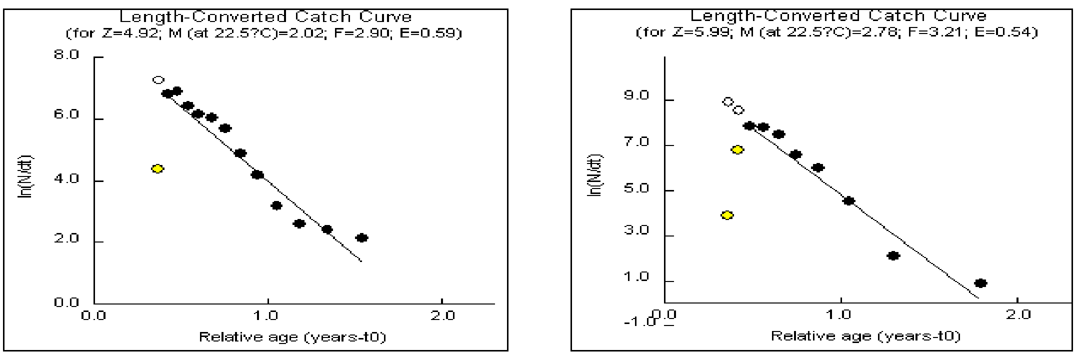

Fig. 4. The linearized catch curve of *O. niloticus* and *O. aureus* caught by trammel net from El-Salam Canal

Table 2. Growth parameters, growth performance, mortality and exploitation rates of *O. niloticus* and *O. aureus* caught by trammel net from El-Salam Canal

Species	L_∞	K	t_o	Z	M	F	E	Φ
O. niloticus	24.86	1.3	-0.0075	4.92	2.02	2.9	0.59	2.91
O. aureus	19.14	1.9	-0.0019	5.99	2.78	3.21	0.54	2.84

Probability of capture. The estimation of the selection (probability) parameters based on the running average method is incorporated with the length-converted catch curve **(Gayanilo *et al.*, 1997)**. The mesh size is highly associated with the length at first capture **(Al-Sayes *et al.*, 2012)**. L_{50} values at which 50% of the fish that become vulnerable to capture were estimated to be 9.94 and 10.82 for *O. niloticus* and *O. aureus*, respectively. A narrow selection range ($L_{75} – L_{25}$) was found to be 1.51cm for *O. niloticus* and 1.52cm for *O. aureus*, indicating the higher selection of such trammel nets, especially towards small fish lengths (Table 3 & Fig. 5).

Table 3. Estimated sizes at 25, 50 and 75 % probability of capture of *O. niloticus* and *O. aureus* caught by trammel net from El-Salam Canal

Species	L_{25}	L_{50}	L_{75}
O. niloticus	9.19	9.94	10.7
O. aureus	10.07	10.82	11.59

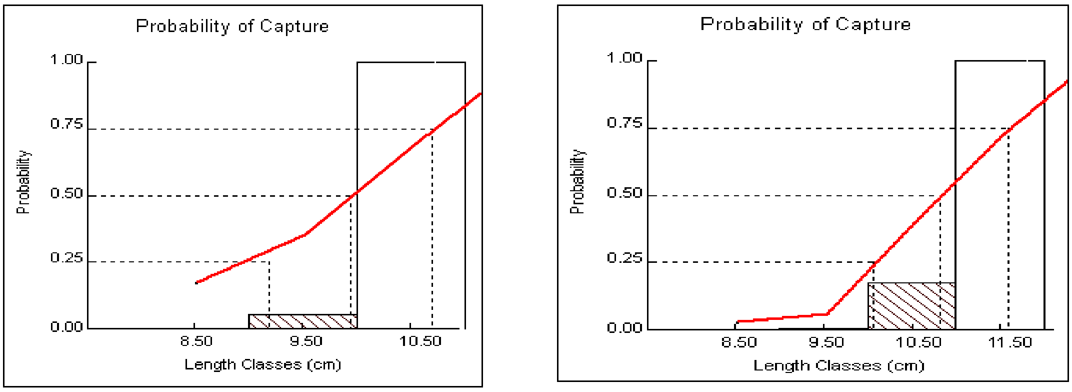

Fig. 5. Probability of length at first capture of *O. niloticus* (right) and *O. aureus* (left) caught by trammel net from El-Salam Canal

Yield per recruit. The relative yield-per-recruit (Y'/R) of *O. niloticus* was determined as a function of Lc/L∞ and M/K (Fig. 6a). The current exploitation (E=0.59) of population is near the maximum allowable limit based on yield-per-recruit calculation (E_{max}=0.61) and exceeds both E_{10} (0.52) and the optimum value (0.50), as suggested by **Gulland (1971)**. In addition, the same trend was exhibited by the current exploitation of *O. aureus* (E=0.54) (Fig. 6b), exceeding Gulland value and E_{50} (0.38) that save 50% of the relative biomass.

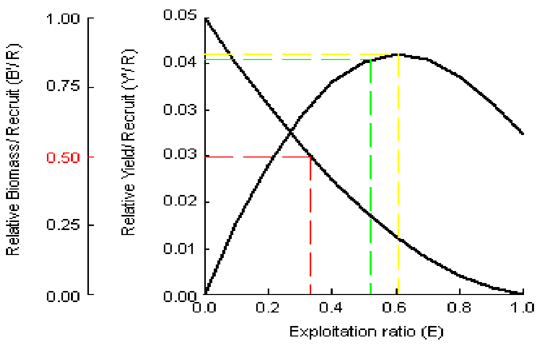

Fig. 6(a). Relative yield per recruit (Y/R)' of *O. niloticus* caught off El-Salam canal

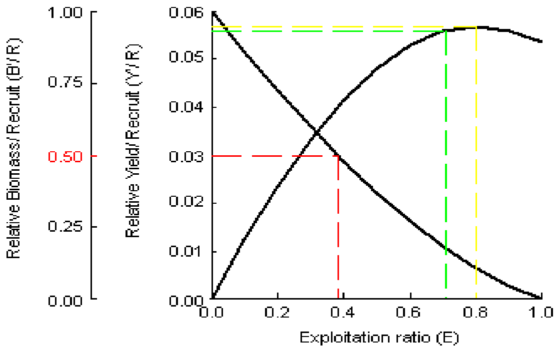

Fig. 6(b). Relative yield per recruit (Y/R)' of *O. aureus* caught off El-Salam canal

DISCUSSION

Each fish species' ability to grow is a distinctive adaptation supported by the interdependence of the species and its environment (**Weatherley, 1972**). Using otolith or scale readings and length frequency methods, previous growth was estimated based on average lengths or weights at capture **(Arias, 1980; Chauvet, 1981)**. In the present study, the results revealed that the longevity of *O. niloticus* was 4 years. The same results were proved by **Shalloof (1991)** in Manzala Lake, **El Shazly (1993)** in Maryut Lake, **Shalloof and El- Far (2009)** in Abu- Zabal Lakes and **Hassan and El-Kasheif (2013)** in Beni Suef region of the River Nile. However, the age of *O. niloticus* was determined to be 2 years in the study of **Bakhoum and Abdallah (2002)** in Manzala Lake and it was estimated at 6 years by **Mehanna (2005)** in Wadi El-Raiyan first lake (length range 14 – 43.1 cm) , while it reached 3 years at the second Lake (L. R. 12.25.8-cm T. L.). However, the age of *O. niloticus* (L.R. 8 - 31.1 cm T.L.) was estimated at five years by **Mehanna *et al.* (2020)** in Manzala Lake and by **Mahmoud and Mazrouh (2008)** and **Khallaf *et al.* (2020)** in the River Nile. On the other hand, the age of *O. aureus* in the present work was 3 years, which is not similar to previous studies carried out at lake Manzala by **Bakhoum and Abdallah (2002)** in southeast (region B) of Manzala Lake. The current findings are also different from the studies of **Mehanna (2004)** in Wadi El-Raiyan lakes and **Shalloof and El-Far (2009)** in Abu- Zabal Lakes. The age of this fish was estimated at four years by **Bakhoum and Abdallah (2002)** in southeast (region B) of Manzala Lake and at 5 years by **Mahmoud and Mazrouh (2008)** in Rosetta branch of the River Nile. This variation in age estimation is mostly due to the methodologies employed to compute age and the study region where the sample was collected **(Daoudi *et al*., 2020)**.

The hypothetical maximum length (L_∞) value for *O. niloticus* was 24.86cm which is higher than that recorded in the work of **El-Bokhty (2010)** in Manzala Lake for fish caught by both trammel net and basket traps. Nevertheless, it was less than the values recorded by some studies in different locations in Egypt; **Mehanna *et al*. (2020)** recorded that the maximum L_∞ reached 34.51-cm; L.R. 8- 31.1cm T.L., and other studies reported values higher than those of the present study, including **El-Bokhty (2006)**, **Mahmoud and Mazrouh (2008)**, **Shalloof and El- Far (2009)**, **El-Bokhty *et al*. (2013)**, **Hassan and El-Kasheif (2013)** and **El-Bokhty and El-Far (2014a)**. For

O. aureus, the hypothetical maximum length ($L\infty$) value was 19.14cm, and this value coincides with that of **Al-Sayes *et al*. (2012)** in Borollus Lake using for fish caught by Tarammel (19.32-cm). On the other hand, it is higher than that registered for fish caught by Lokaffa, Basket trap and Al- Qerba. Additionally, the current value is higher than that of **El-Bokhty (2010)** in Manzala Lake using basket traps, while it is less than that recorded by **El-Bokhty (2010)** in Manzala Lake for fish caught by trammel net. Furthermore, the present value is less than that suggested by **Mehanna (2004)**, **El-Bokhty (2006)**, **Mahmoud and Mazrouh (2008)** and **Shalloof and El-Far (2009)**. The same species, age, sex, maturity, and sample period were the causes of the variances in growth parameters **(Mcllwain *et al*., 2005)**. Otherwise, the variation in growth parameters between the different sites may be due to the variation in the maximum size of the fish in the samples used **(Mehanna *et al.* 2010)**. This difference may be attributed to sample variations between the fishing gears **(Dalzell,1996)**.

Lengths at first capture, as estimated from the probability of capture (L_c) at which 50% of the fish become vulnerable to capture were 9.94cm for *O. niloticus*. The L_c in the present work is less than that recorded (14.4-cm) by **El-Bokhty (2010)** and **Mehanna *et al*. (2020)** in Manzalla lake. Concerning the length at first capture, the L_c of *O. aureus* was 10.82cm; this value is less than that recorded in the study of **Mehanna (2004)** in Wadi El- Raiyan and that of **Al-Sayes *et al*. (2012)** in Borollus Lake for fish caught by trammel. But, it's higher than that found by **Al-Sayes *et al*. (2012)** in Borollus Lake for fish caught by Lokaffa, basket trap and Al-Qerba, and the same in Manzalla Lake according to **El-Bokhty (2006)** and **El-Bokhty (2010)** and in the River Nile according to **Mahmoud and Mazrouh (2008)**. The variations in L_c values is attributed to the mesh size of the inner layer of trammel nets used among different localities and different gears used in sampling. A narrow selection range (L_{75} – L_{25}) was 1.51 cm for *O. niloticus* and 1.52cm for *O. aureus*, and this indicates the high selectivity of this net. Despite the high selectivity of this net, it tends to catch small sizes due to the smaller mesh sizes of the inner layer of these nets. Therefore, **El-Bokhty (2022)** recommended to use larger inner layer mesh bar length of 3cm at least to gain extra weight and give more reproduction opportunities.

Exploitation indices (E) for *O. niloticus* in the present work was 0.59. This value is similar to those recorded by previous studies in other localities revealing the a higher effort exerted. These values ranged from 0.51 to 0.69 (**El-Bokhty, 2006, Mahmoud & Mazrouh, 2008; El-Bokhty, 2010; El-Bokhty *et al*., 2013; Hassan & El-Kasheif, 2013, El-Bokhty & El-Far, 2014a; Mehanna *et al*., 2020)**. On the other hand, the exploitation indices (E) for *O. aureus* was 0.54, which is less than the values recorded for fish caught by trammels at Manzala Lake by **Mehanna (2004)**, **El-Bokhty (2006)**, **Mahmoud and Mazrouh (2008)** and **El-Bokhty (2010)**. According to **Gulland (1971)**, the optimum exploitation ratio (E) should be 0.5. While, the **GFCM (2013)** considered that if E is more than 0.5, overexploitation of fish population is indicated, and if is less than 0.4 it would mean that the studied fish is under exploitation. Accordingly, exploitation indices (E) in the present work indicates that both *O. niloticus* and *O. aureus* fisheries are overexploited.

Table (4) shows the growth parameters (L_∞ and K), length at first capture (L_c) and exploitation indices (E) of *O. niloticus* and *O. aureus* from different water bodies in Egypt.

Growth and mortality estimation coefficients are used to assess the status of diverse fish populations and as a set of input variables for **Beverton and Holt (1957)** and **Pet *et al*. (1996)** as an example of bio demographic models. These models are applied to predict consequences of management measures such as the effect of changes in effort and mesh size on the yield **(El-Bokhty, 2006)**. For the value of natural mortality (M) of the present *O. niloticus*, it was 2.02 y^{-1}; the value of fishing mortality (F) was 2.9 y^{-1} and the mean of total mortality (Z) was 4.92 y^{-1}. While, in Manzala Lake, **Mehanna *et al*. (2020)** found that, the Z = 2.02; M = 0.82, and F = 1.20 $year^{-1}$. Furthermore, **El-Bokhty (2010)** recorded that Z = 4.33, M = 1.79 and F = 2.54 $year^{-1}$ of fish caught by trammel net, but for fish caught by traps net, Z, M, F were 4.94, 1.89 and 2.34 $year^{-1}$, respectively.

This variation in mortality parameters may result from the efforts exerted by different fishing gears, different specifications as well as the difference in the mesh sizes of these nets and fishing localities **(El-Bokhty, 2010)**. The exploitation rate of *O. niloticus* (0.59) exceeds the optimal value (E_{opt} = 0.50) according to **Gulland (1971)**. The fishing mortality (F=2.9 $year^{-1}$) is higher than the natural mortality (M=2.02 $year^{-1}$), indicating a higher fishing effort. Consequently, the current exploitation rate indicates an overfishing situation for *O. niloticus* as well as *O. aureus*.

Table 4. The growth parameters (L_∞ and K), length at first capture (L_c) and exploitation indices (E) of *O. niloticus* and *O. aureus* from different water bodies of Egypt

Location	Species	The gear	L_∞(cm)	K(y^{-1})	L_c(cm)	E	Author
El- Salam Canal	*O. niloticus*	Trammel	24.86	1.3	9.94	0.59	Present study
	O. aureus		19.14	1.9	10.82	0.54	
Manzala Lake	*O. niloticus*		34.51	0.38	14.4	0.59	Mehanna *et al.* (2020)
	O. niloticus	Trammel	22.67	1.10	11.45	0.59	El-Bokhty (2010)
		Basket traps	18.52	1.10	11.66	0.62	
	O. aureus	Trammel	22.66	1.10	8.89	0.64	
		Basket traps	18.24	0.94	8.6	0.64	
	O. niloticus		28.88	0.53	7.07	0.69	El-Bokhty (2006)
	O. aureus		21.53	0.59	6.33	0.59	
Burullus Lake	*O. niloticus*		26.29	0.81	9.47	0.58	El-Bokhty *et al.* (2013)
	O. aureus	Lokaffa	18.28	0.87	7.64	0.45	Al-Sayes *et al.* (2012)
		Trammel	19.32	0.41	11.24	0.45	
		Basket trap	17.19	0.42	10.70	0.28	
		Al-Qerba	14.55	0.39	8.34	0.33	
River Nile	*O. niloticus*		25.73	0.73	14.10	0.60	El-Bokhty and El-Far (2014a)
		2.4 cm mesh bar			11.89		El-Bokhty and El-Far (2014b)
		2.8 cm mesh bar			12.22		
			48.14	0.15		0.58	Hassan & El-Kasheif (2013)
	O. niloticus		28.50	0.39	9.5	0.51	Mahmoud & Mazrouh (2008)
	O. aureus		26.40	0.40	10.5	0.61	
Abu- Zabal Lakes	*O. niloticus*		34.59	0.13			Shalloof &El- Far (2009)
	O. aureus		45.23	0.07			
Wadi El-Raiyan	*O. aureus*		27.15	0.56	15.28	0.85	Mehanna (2004)

CONCLUSION

The maximum growth of *O. niloticus* and *O. aureus* caught by trammel net from El Salam Canal was in the first year of life. The *O. niloticus* fishery as well as *O. aureus* fishery are considered to be over-exploited since they exceeded the optimum (0.5) limit. These trammel nets used in El Salam Canal have a narrow meshed inner layer as reflected from the smaller values of L_c; therefore, the illegal nets should be forbidden. Furthermore, more studies are needed to stand on the exploitation status of these species under the fishing effort of other fishing gears operating in the canal.

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