Age, Growth and mortality for management of *Sarotheradon galilaeus* (Teleostei: Cichlidae) in Lake Manzala, Egypt

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Abstract

The maximum age of *Sarotherodon galilaeus* in Lake Manzala was four years. The Length and weight relationship was expressed as $W=0.0132L^{3.1025}$. Also, the growth coefficients were L∞ and K, 28.06 cm, 0.45/yr, and -0.1, respectively. Height at first capture was Lc=10.26 cm with corresponding age Tc=0.85 years. This means that the stock of *S. galilaeus* in Lake Manzala is being overexploited. For management purposes, the exploitation ratio should be reduced from 0.77 to 0.50 (27%) to maintain the reproductive biomass of this species. The study also showed that the total mortality was (Z=3.28/year), natural deaths (M=0.56/year) and fishing mortality (F=1.82 / year) to the utilization rate of E=0.77. The high values of F and E reflect the high level of exploitation of this species in Lake Manzala. So, for management purposes and to maintain the stocks of *S. galilaeus*, the fishing mortality rate must be reduced by at least 27% from its current level to achieve sustainability for this species.

Keywords: Population dynamics, Mortality rate, *Sarotheradon galilaeus*, Lake Manzala

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Introduction

Lake Manzala one of largest northern Lakes and it is highly important source of inland fishery production in Egypt where give 42.68% of the Northern lakes production while, other the Egyptian lakes give 33.42% of production. The location of Lake Manzala in the north-east of the Egyptian delta, it is on the North by the Mediterranean Sea, the Suez Canal on the East, the River Nile on the West and on the South by the Husseini Plain and overlooks four governorates (in the East Port Said, in the North the Damietta, in the South Sharkia and in the West the Dakahlia). The lake (225214) acres and the total production were 65113 tons of fish annually according to (GAFRD, 2018).

The cichlids are esteemed as food; its price is fisheries worldwide Imteazzaman and Galib (2013). Family Cichlidae is one of the major commercial suitable for a large segment of the Egyptian people and it supports both small-scale fishery and commercial fish species commonly caught in the River Nile and it is one of the most desirable species. And it is lived in the Nile River also, its tributaries as well as the Northern Delta lakes (Manzalah, Borollus, Edku, and Mariut), Lake Qarun, Wadi El-Raiyan, and Lake Nasser. Also, this family is cultured in farms all around Egypt (Mahmoud *et al.,* 2013). In terms of human activities, the major threats to river systems and lakes throughout the world are pollution, overfishing, destruction lakes ecosystems (Galib *et al.,* 2016 and 2018).

Tilapias are the second most widely farmed fish in the world after carps, with a global production of 6.3 million tons in 2018 (FAO, 2019). Tilapia is the common name of cichlid species live to Africa. The family of Cichlidae consists of three important genera namely Oreochromis, Sarotherodon, and Tilapia. Genus Tilapia contains more than 70 species (Meyer, 2002) and it is mainly found in Africa and many parts of the Middle East also, these species are found in many other types of water in the world. Because of their economic importance in Egyptian water, they have been highlighted in many articles that study their biology and fisheries for this species such as (Adam 2004; Abaza 2004; Mehanna 2005; El-Sayed 2006; Mahmoud and Mazrouh, 2008). *Sarotherodon galilaeus* (Linné, 1758) species belongs to family: Cichlidae Sub-order: Percoidei, Order: Perciformes, Super Order: Acanthopterygii and Subclass: Actinopterygii. This species exhibits grew silvery color on the fins and sides and juveniles show some black vertical lines on the sides (Leveque *et al.*, 1992; Leveque, 1997).

For proper exploitation and fisheries management, must be study the relationship between length-weight species (Keivany *et al.,* 2015; Qamar *et al.,* 2017). Relationship length with weight is required for setting up yield equation (Beverton and Holt, 1957; Ricker, 1968). The isometric and allometric relationships based on regression analysis are still successful to estimate the body composition in fish and other animals in the production sector (Dumas *et al.,* 2010). Fish in optimal physiological condition should grow and reproduce successfully thus ultimately ensuring sustainability of the population (Rose, 1989).

Although *S. galilaeus* is one of the most important components of the artisanal fishery and widespread in the Northern lakes of Egypt, knowledge on their biology and population dynamics on national and international levels is limited (Yamaguchi *et al.,* 1990; El-Bokhty 2006; Mahmoud and Mazrouh, 2008; Lederoun *et al.,* 2019). The present study aimed to provide the basic information required for sustainable management and fish population dynamics of *Sarotherodon galilaeus* in Lake Manzala.

Material and methods

Collection of samples

A total of 1380 random samples of *S. galilaeus* were collected monthly from the commercial catch in different landing sites of Lake Manzala (Fig.1) during the period from September 2018 to December 2019. After collection; samples were kept in ice box and transported to fish Population Dynamics Laboratory, Suez Branch, National Institute of Oceanography and Fisheries for further examination. In the laboratory, date and place of capture, total length to the nearest cm, total weight to the nearest 0.1g and sex were recorded for each specimen.

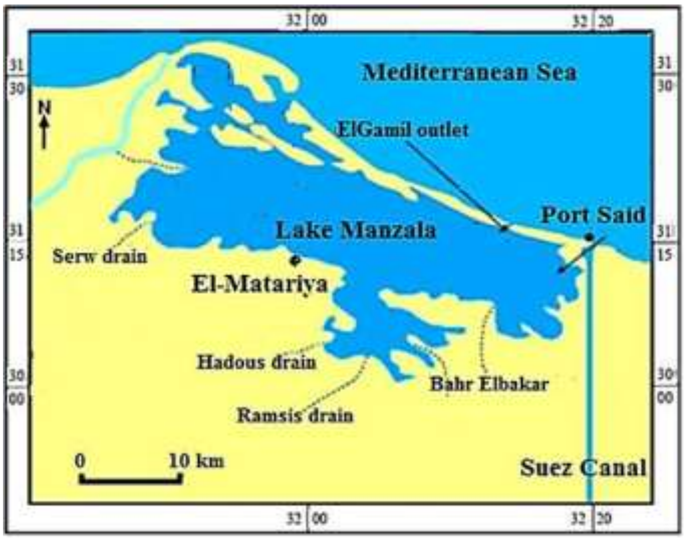

Figure 1. Map of Lake Manzala showing the study area.

Age determination

Scales of *S. galilaeus* were removed, cleaned and kept in special envelopes with full information for subsequent examination relevant to age determinate to determine the age; scales were taken for individual behind the tip of the pectoral fin below the lateral line (Paul, 1968). The scales were cleaned and stored dry in envelopes for the subsequent study. Later on, scales were soaked overnight in 10% solution of ammonium hydroxide solution. About from five to seven scales were placed between two glass slides, and examined by Lica Zoom 2000 microscope. On the clearest scale from each batch, the total scales radius as well as the radius of each annulus was measured to the nearest 0.01cm. The relationship between scales radius (R) and total fish length (TL) was determined according to the formula TL=a+b(R). The back-calculated lengths at the end of each year of life were estimated by Lee (1920) equation as follows:

$L_n=(L_t – a) R_n / R + a$

Where L_n is the length at the end of n years (mm), L_t is the total length at capture (mm), R_n is the scale radius to the n^{th} annulus (mm), R is the total scale radius (mm) and “a” is the intercept with Y-axis from the relationship of length and scale radius.

Length-weight relationship

Length-weight relationship was determined according to the following equation:

$W=aL^b$ Ricker (1975)

Where W=Weight of fish in g, L=Total length of the fish in cm and a and b are constants whose values are estimated by the least square method.

Growth parameters

The Von Bertalanffy growth model was applied to describe the theoretical growth of *S. galilaeus.* The constants of the von Bertalanffy model ($L\infty$ and K) were estimated by using Ford (1933)-Walford (1946) plot.

Length (L_c) and age (T_c) at first captur

The length at first capture (the length at which 50% of the fish at that size are vulnerable to capture) of *S. galilaeus* was estimated by the analysis of catch curve using the method of Pauly (1984) and the corresponding age at first capture (T_c) was obtained by converting L_c to age using the Von Bertalanffy growth equation as the follows:

$T_c= -1/K \ln(1-L_c/L_\infty)+t_o$

Mortalities

The total mortality coefficient (Z) of *S. galilaeus* was estimated as the mean of two different methods; linearized catch curve method of (Pauly, 1983) and cumulative catch curve of (Jones and Van Zalinge, 1981) which based on frequency data. While, the natural mortality coefficient (M) is calculate as the geometric mean of three different methods (Taylor, 1960; Ursin, 1967; Pauly, 1980). Accordingly, the fishing mortality coefficient (F) was estimated by subtracting the value of natural mortality (M) coefficient from the value of total mortality coefficient (Z) as F=Z-M

Exploitation ratio (E)

The exploitation ratio or expectation of death from fishing during some specified period when all causes of death are affecting the population was calculated according to the relation (Gulland, 1971).

E=F/Z

Results

Age and growth in length:

In the present study, the catch of *S. galilaeus* composed of five age groups from Zero to five and age group one was the most frequent one. Scales reading for 1380 individuals showed four age classes of *S. galilaeus*. Age groups and growth in length (average back–calculation lengths) were calculated for *S. galilaeus* as 11.95cm, 17.46cm, 21.85cm and 23.88cm for 1st, 2nd, 3rd and 4th years respectively (Fig. 2). It is also evident that *S. galilaeus* attain their highest growth in length at the end of the first year of life 11.95cm after which the annual increment in length decreases gradually with further increase in age until reaches its minimum value at the end of last year of life 4th year (Fig. 3).

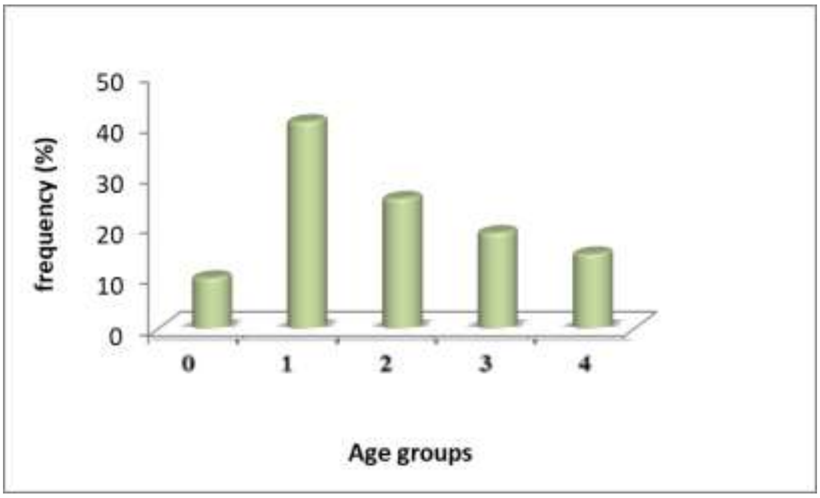

Figure 2: Age composition of *S. galilaeus* from Lake Manzalah during September 2018 to December 2019.

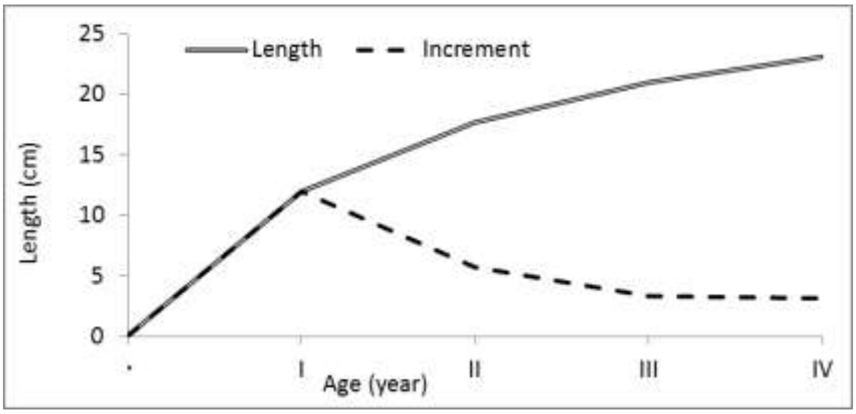

Figure 3: Back-calculated length (cm) and growth increment at the end of each year of life of *S. galilaeus* from Lake Manzalah, during September 2018 to December 2019.

Growth in weight

The weight at the end of each year of life for *S. galilaeus* was calculated by applying the corresponding length-weight equation to the back-calculated length. The mean weight for each age group is estimated to be 29.05g 94.19g, 188.90g and 248.84g during the fourth years of life respectively. It is clear that, the growth in weight is much slower in the first year of life and annual increment in weight increase with further increase in age until reaches its maximum value at age group (III), after which a gradual decrease in annual increment is observed. By following the input in weight throughout the different years of life it is found that, the highest input in weight takes place at the end of the third year of life, 188.90g. While the lowest input in weight is recorded at the end of the first year of life 29.05g (Fig. 4).

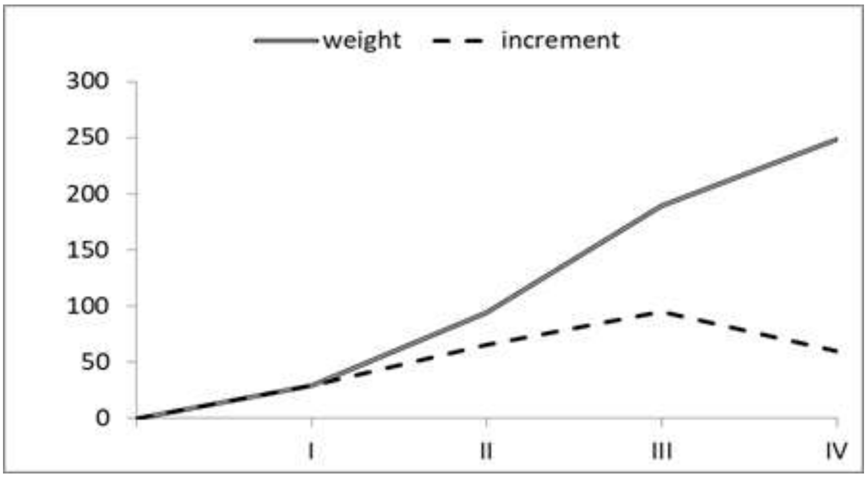

Figure 4: Calculated weight (g) and annual increment at the end of each year of life of *S. galilaeus* from Lake Manzala, during September 2018 to December 2019.

Length weight relationship

In the present study, the total length of *S. galilaeus* ranged between 8.5cm to 24.5cm, while their total weights are varied between 10g and 275g. The weight of the fish increases with the increasing length of the fish. The length weight relationship (Fig. 5) was described by the power equation as:

$W = 0.0132L^{3.1025}$ (R2=0.95)

Data revealed that, the values of "a" and "b" were: 0.0132 and 3.1025 respectively. From the above findings, it is clear that, b value (3.1025) is ideal, indicating a tendency towards the isometric growth. The correlation coefficient "R^2" was 0.95, which is a very good correlation between length and weight (Fig. 5).

Growth parameters

The growth model of Von Bertalanffy was applied to describe the theoretical growth of *S. galilaeus* in Lake Manzala. The obtained $L\infty$ and K and t_o of *S. galilaeus* was 28.06cm and 0.45/year and -0.1, respectively.

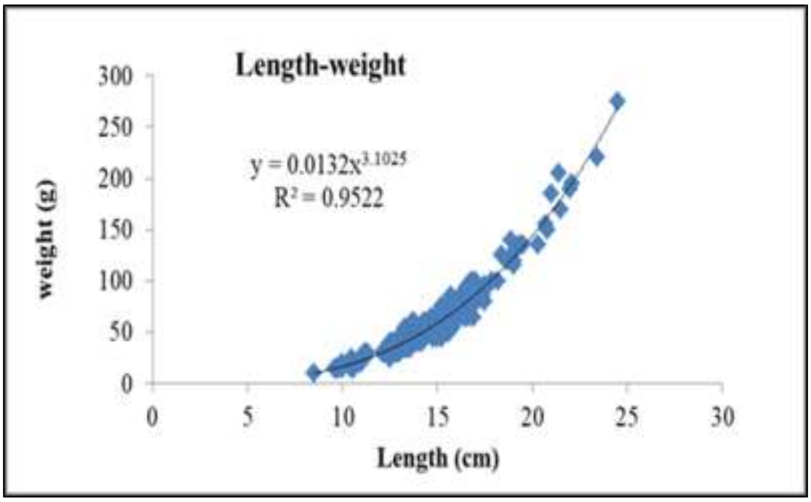

Figure 5: Curvilinear relationship between total length (TL) and body weight (W) of *S. galilaeus* from Lake Manzala, Egypt.

Length and age at first capture L_c and T_c

The length group frequency percentage of *S. galilaeus* was cumulated separately and a cumulative curve was drawn to estimate the length at first capture L_c (Fig. 6) was found to be 10.26cm and the corresponding age was equal to (T_c) 0.85year.

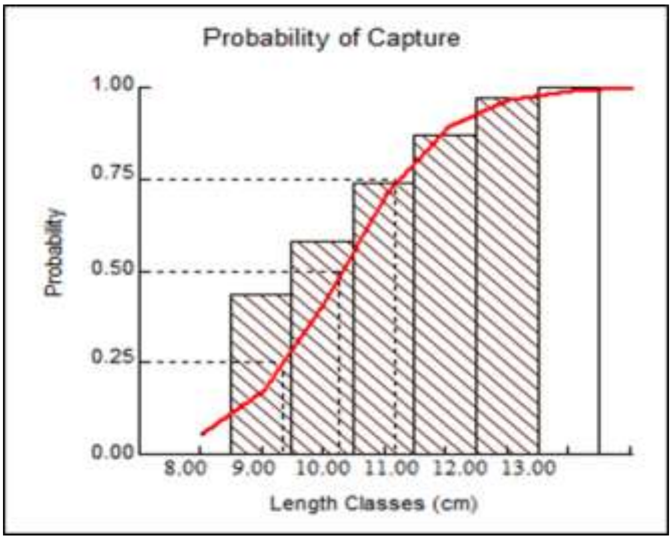

Figure 6: Length at first capture of *S. galilaeus* collected from Lake Manzala, Egypt.

Mortality and Exploitation ratio (E)

The mean total mortality coefficient (Z) of *S. galilaeus* collected from Lake Manzala was estimated at 2.38/year. While, mean the natural mortality coefficient (M) was calculated at 0.56/year. Correspondingly the fishing mortality coefficient (F) was 1.82/year. The exploitation ratio (E) of *S. galilaeus* collected from Lake Manzala was estimated at 0.77 (Fig.7).

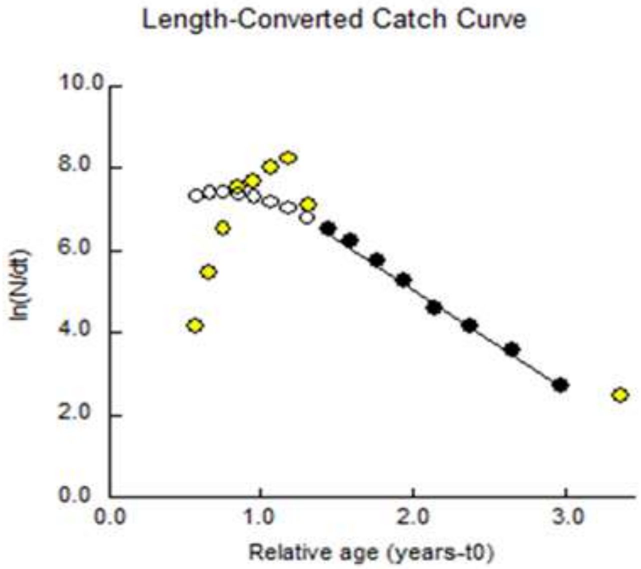

Figure 7: Length-converted catch curve for *S. galilaeus* collected from Lake Manzala, Egypt.

Discussion

One of the most important parameters in the field of fisheries management is Age determination. It is the basic requirement for knowledge to evaluate longevity, growth rate, mortality rate and yield. Also, it is the basic information needed for the construction of a management strategy rational exploitation of any exploited fish stocks mentioned by (Mehanna, 1996).

It is well-known that the age of fishes can be determined directly by the examination and interpretation of the periodic annuli formed on the different skeletal parts of the fish such as scales, otolith, vertebrae, fins, spines and operculae. The most widely using hard structures in age determination were scales and first-time used by (Hoffbauer, 1898). The present study used the scales to determine the age of *S. galilaeus* and the results revealed that the scales were a reliable tool for aging this species. Maximum age for *S. galilaeus* differs among locations, and lifespan does not appear to be linked with size. In this study the longevity of *S. galilaeus* is estimated to be 4 years in Lake Manzalla by counting the annual growth rings on its scales. Similar results were recorded by (El-Bokhty, 2006) at the same lake based on length frequency distribution. (Mahmoud *et al.*, 2013) recorded 5 years at Nozha Hyrdrodrome. The difference in longevity according to the location also, may be due to record maximum size and the difference in method used or to the personal error in reading the hard structure. The present study showed that, the most frequent age group for *S. galilaeus* was group one forming up to 41% of the total catch. This means that, *S. galilaeus* in Lake Manzalla become entered into the artisanal fishery at age one year. And this is the indication for

S. galilaeus exposure to overexploitation in these Lake.

Attain *S. galilaeus* highest growth rate in length during the first year of life in the back-calculated length at the end of each year of life, after which with further increase in age noticed a gradual decrease in growth increment. This result was in agreement with the previous studies (Moreau *et al.,* 1986; Yamaguchi *et al.,* 1990; de Feu 2003; El-Bokhty, 2006; Kwarfo-Apegyah and Ofori-Danson, 2010; Mahmoud *et al.,* 2013; Lederoun *et al.,* 2019; Akongyuure and Edziyie, 2020). They were stated that fish in the young stages characterized by a higher growth rate than that the old ones and the maximum growth rate in length were in the first year of their life. This is may be due to the energy that comes from the feeding is used in only growth in early stages of the fish and converted to gonads formation in adult stages.

In this study, the first year of the life *S. galilaeus* the growth in weight were slow and increases with in age until reaches its maximum rate at age group (III), after which a gradual decrease in annual increment . This indicates that *S. galilaeus* should be protected until the third year of life to achieve a pronounced yield to keep on biomass.

The length-weight relationship has a great importance in the field of fish biology and fisheries management. It is used for the calculation of the total yield of fish caught when the length and the number are known. It serves also in the conversion of the length to the weight or vice versa and the study of the variation in the expected weight for a length of fish as an indication of gonad development or fatness (Mehanna, 1996). Also, length and weight data are essential for a wide number of studies, for example estimating growth rates, age structure, and other aspects of fish population dynamics (Kolher *et al.,* 1995).

In the present study, the obtained length weight relationship indicated that the length weight is isometric for *S. galilaeus* (b= 3.1025). These results showed that the weight of the fish increases to power greater than the cube of the length and this indicates that the body weight changed rapidly with the increasing the body length. Similar observations were detected in different fish by many authors notably by (Mahmoud *et al.,* 2013) for *S. galilaeus* (2.90) at Nozha Hydrodrome and (Shalloof and El- Far, 2017) for *S. galilaeus* (3.0154) at Rosetta branch. This finding may reflect the higher fertility and the suitable environmental factors (especially feeding behaviors). Aleen (1938) concluded that the ideal “b” value is 3. However, Hile, (1936) and Le Cren (1951) reported that, the fish in which the value of “b” ranges between 2.5 to 4 live also in good conditions. This means that *S. galilaeus* (b= 3.1025) is live in good environmental conditions.

The mathematical description of growth is of a great importance in the field of fisheries management and fish stock assessment. The obtained growth parameters (L_∞, K and t_o) are the basic input data into various models used for managing and accessing the status of the exploited fish stocks. Besides, the mathematical descriptions of the growth facilitate the comparison between growth of fishes belonging to different species or to the same species at different times and different localities. Several models have been developed for the mathematical description of growth, from which the Von Bertalanffy growth model is the most widely used (Zaahkouk *et al.,* 2017; Mehanna *et al.,* 2019).

In the present study, the growth model of Von Bertalanffy (1938) was applied to describe the theoretical growth of *S. galilaeus* in Lake Manzalla. The results showed that L_∞ (28.06cm) was lower than that estimated at the same species by Moreau *et al.* (1986) at Lake Kainji, Nigeria (48.4cm) and Lak Nasser, Egypt (41cm); Yamaguchi *et al.* (1990) at Hight Dam Lake, Egypt (28.8cm); de Feu (2003) at Lake Kainji, Nigeria. (45.7cm); Kwarfo-Apegyah and Ofori-Danson (2010) at Ghana (36.75cm) and higher than that estimated at the same species by Moreau *et al.* (1986) at Lak Manzala, Egypt (20.1cm); El-Bokhty (2006) at Lake Manzala, Egypt (23.63cm); Mahmoud *et al.* (2013) at Nozha Hyrdrodrome, Egypt (24.2); Lederoun *et al.* (2019) at Lake Doukon, Benin (26.2cm) and Lake Togbadji, Benin (23.6cm) and Akongyuure and Edziyie (2020) at Northern Ghana (27.30cm). The lower and higher values of L_∞ may be resulted from the difference in the recorded length range, the method used and/or the stress of water pollution (Mansour, 2004).

The growth coefficient value (K=0.45/year) of *S. galilaeus* reflected that the growth of this species is more suitable for than that estimated at the same species by Moreau *et al.* (1986) at Lak Nasser, Egypt (0.29/year); El-Bokhty (2006) at Lake Manzala, Egypt (0.27/year) and Kwarfo-Apegyah and Ofori-Danson (2010) at Ghana (0.30/year). While, less well in growth than recorded by Moreau *et al.* (1986) at Lake Kainji, Nigeria (0.47/year) and Lak Manzala, Egypt (0.53/year); Yamaguchi *et al.* (1990) at Hight Dam Lake, Egypt (0.68/year); de Feu, (2003) at Lake Kainji, Nigeria. (0.47/year); Mahmoud *et al.* (2013) at Nozha Hyrdrodrome, Egypt (0.98/year); Lederoun *et al.* (2019) at Lake Doukon, Benin (0.73/year) and Lake Togbadji, Benin (0.87/year) and Akongyuure and Edziyie (2020) at Northern Ghana (0.76/year).

In the present study, length at first capture (L_c) was estimated to be 10.26cm and the corresponding age (T_c) was 0. 85/year for *S. galilaeus* in Lake Manzalla. This means that the stock of *S. galilaeus* in Lake Manzalla is highly overexploited. For management purposes, the exploitation ratio of *S. galilaeus* should be reduced from 0.77 to 0.50 (27%) to maintain the spawning biomass.

In the present study, the formulae suggested by Taylor (1960), Ursin (1967), and Pauly (1980) were applied to estimate the natural mortality

coefficient of *S. galilaeus*. The results indicated that, total mortality (Z) of *S. galilaeus* at Lake Manzalla (Z= 3.28year^{-1}) was higher than that reported for the same species by El-Bokhty (2006) at Lake Manzalah, Egypt (Z= 1.02year^{-1}); Mahmoud *et al.* (2013) at Nozha Hyrdrodrome, Egypt (Z= 0.825year^{-1}); Lederoun *et al.* (2019) at Lake Doukon, Benin (Z= 1.76year^{-1}) and Lake Togbadji, Benin (Z= 2.21year^{-1}).
While, the natural mortality of *S. galilaeus* (M= 0.56year^{-1}), was matching with that recorded at the same species by Mahmoud *et al.* (2013) at Nozha Hyrdrodrome, Egypt (M= 0.519year^{-1}) and lower than that estimated at the same species by El-Bokhty (2006) at Lake Manzalah, Egypt (M= 0.71year^{-1}); Lederoun *et al.* (2019) at Lake Doukon, Benin (M= 1.51 year^{-1}) and Lake Togbadji, Benin (M= 1.74year^{-1}).

Accordingly, the fishing mortality of *S. galilaeus* (F=1.82) showed an over exploitation of this species where the exploitation level was higher than the ideal one (E=0.77), such over exploitation was reported in other localities such as Nozha Hyrdrodrome, Egypt (Mahmoud *et al.*, 2013) Lake Doukon, Benin and Lake Togbadji, Benin (Lederoun *et al.,* 2019).
The exploitation ratio is very important to estimate the state of the stock which optimum, underexploited and overexploited. The obtained results showed that *S. galilaeus* is overexploited where the estimated E value was 0.77 in Lake Manzalla. Gulland (1971) suggested that, a fish stock is optimally exploited at a level of fishing mortality that generates E=0.50, where optimum fishing mortality equal the natural mortality (F= M). Pauly (1987) proposed a lower optimum fishing mortality (E=0.40).

Conclusion

For management purposes and to maintain the stocks of *S. galilaeus* in Lake Manzalla, the fishing mortality should be decreased by at least 27% of its current level and Regulation of mesh sizes, Increase the awareness of bad impact of fishing and marketing of small fishes should be encouraged. Revision of fisheries laws and applies strict punishment toward illegal fishers

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