International Journal of Fisheries and Aquaculture Research
Vol.9, No.2, pp.33-53, 2023
Print ISSN: ISSN 2397-7507,
Online ISSN: ISSN 2397-776
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

Growth Pattern of the Golden Gray Mullet, *Liza Aurata* (Mugilidae) in the Southern Mediterranean Coast (Libya)

Alia Salem Elshakh[1], Ramadan A. S. Ali[2,*], Sayed Mohamed Ali[2], Ahmad GH. Younis[3]
1: Department of Zoology, Faculty of Science, University of Omar Al-Mukhtar, Darnah, Libya
2: Department of Zoology, Faculty of Science, University of Omar Al-Mukhtar, Albaida, Libya
3: Department of Marine Sciences, Faculty of Science, University of Omar Al-Mukhtar, Albaida, Libya
* Corresponding author < ramadan.atea@omu.edu.ly>

doi: https://doi.org/10.37745/ijfar.15/vol9n23353 Published January 21, 2024

Citation: Elshakh A.S., Ali R.A.S., Ali S.M., Younis A.G.H. (2023) Growth Pattern of the Golden Gray Mullet, Liza Aurata (Mugilidae) in the Southern Mediterranean Coast (Libya), *International Journal of Fisheries and Aquaculture Research*, Vol.9, No.2, pp.33-53

ABSTRACT: *This study aimed to establish the von Bertalanffy growth model of the golden gray mullet Liza aurata in lagoonal habitats of the southern Mediterranean, as exemplified by Umm Hufayn, a brackish lagoon in eastern Libya. Eighty L. aurata fish collected randomly from the artisanal catch of Umm Hufayn were used in the study. The length-weight relationship, and the fish length-at-age data, used to calculate the von Bertalanffy parameters (L_∞, K, t_0, and W_∞) were obtained from another two complementary studies based on the same 80 fish sample. Four aging techniques were used: counting annuli on opercula and scales, the fish-length frequency distribution, and the "average" of the three techniques. The mean length of the studied fish was 21.33cm, corresponding to a mean weight of 89.01g. The established von Bertalanffy growth models were: L_t=56.765*(1-exp(-0.070*(t+4.440))), Ø′ =2.3532, based on opercula; L_t=39.02*(1-exp(-0.1645*(t+2.8))), Ø′ =2.3987, based on scales; L_t=40.0313*(1-exp(-0.1549*(t+3.0204))), Ø′ =2.3949, based on the length Frequency distribution, and L_t=49.7049*(1-exp(-0.0949*(t+3.9573))), Ø′ =2.370, based on the "average". The model obtained from grand averaging of L_∞, K, t_0, and W_∞ obtained from the four aging techniques was L_t=45.2704*(1-exp(-0.1298*(t+3.42))), Ø′ =2.4249. The predictability of all these models was high, as can be concluded from the close values of their Ø′, and the closeness of the predicted length-at-age values to measured values; their plots almost overlapped. Derivatives of the above models (W_t, t_L, Δt) were also calculated.*
KEYWORDS: golden mullet, *Liza aurata*, southern Mediterranean, von Bertalanffy growth, Libya

INTRODUCTION

Liza aurata, Mugilidae, is a medium size Mullet that is an important component of the artisanal catch in eastern Libya and a strong candidate for future aquaculture (Bardach *et al*., 1972). The present study aimed to establish the growth pattern of this fish in Um Hufayan, a brackish lagoon typical of those found scattered along the entire southern Mediterranean Sea coast, based on the von Bertalanffy model (von Bertalanffy, 1934). The morphology of the fish in Um Hufayan was studied by Elshakh *et al*. (2021) and its biological and fisheries indicators by Elshakh *et al*. (2023).

The von Bertalanffy growth model generally conforms best to measured fish growth (Gulland, 1983; Pauly, 1984; and Pauly and Morgan, 1987). It is a length (or weight)-at-age based model, and hence many times is incorporated into more complex fisheries models. Its main function is to predict fish length or weight at a given age or vice versa based on four parameters, L_∞, K, t_0, and W_∞, which are specific for individual fish species in its specific habitat. Values of these parameters are usually calculated from the measured fish length (or weight)-at-age of individual fish in a random sample representative of the original population at sea. L_∞ cm is the mean maximum length that can be reached by very old fish (asymptotic length), while W_∞ g is the asymptotic weight. K yr^{-1} is the curvature parameter; it indicates how fast the length of the growing fish approaches the asymptotic length L_∞. t_0 yr is the initial condition parameter, a mathematical parameter that has no biological significance but means the regressed point in time at which the size of the fish was zero.

Methods

The study site: Um Hufayan (32° 33' 13.5" N, 23° 05' 57.2" E), the habitat of the study fish, is a 2 km^2 shallow (0.5 to 3m deep), brackish (11‰) lagoon located within the Gulf of Bomba in the eastern coast of Libya Mediterranean Sea (Fig. 1). It is a principal artisanal fishing ground, a natural feeding ground for several commercial fishes, and an important wetland (Mohamed, 2019; Elshakh *et al*., 2021).

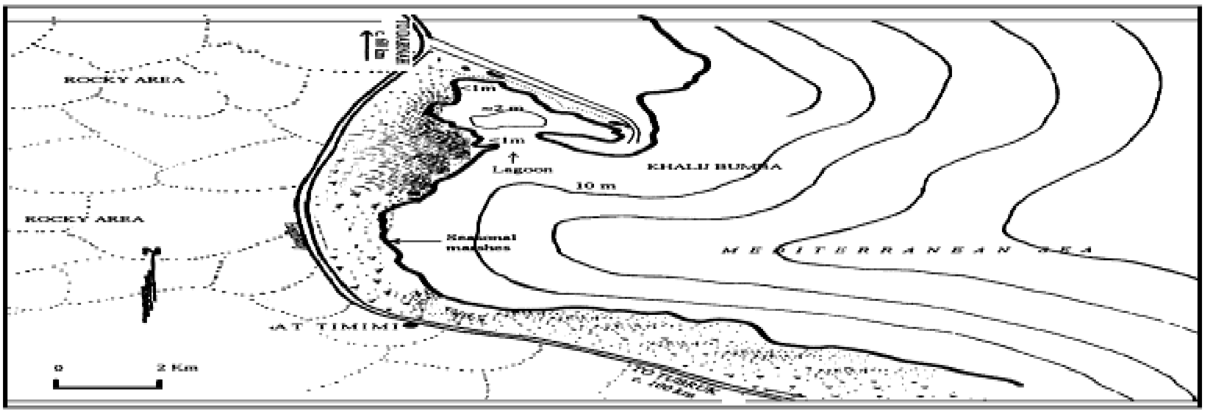

Fig. 1. Um Hufayan Lagoon is located within the Gulf of Bumba, eastern Libya Mediterranean Sea (source: Reynolds, *et al*., 1995).

The von Bertalanffy growth model

The required complete von Bertalanffy model and its derivatives are:

$L_t = L_\infty * \{1 - \exp(-K * (t - t_0))\}$ is used for calculating length-at-age.
$W_t = W_\infty * \{1 - \exp(-K * (t - t_0))\}^b$ is used for calculating weight-at-age.
$t_L = t_0 - 1/K * \ln(1 - L/L_\infty)$ is used for calculating age-at-length.
$\Delta t = t_2 - t_1 = (1/K) \ln((L_\infty - L_1)/(L_\infty - L_2))$ is used for calculating the time interval **(Δt)** taken for the fish to grow from the age t_1 to the age t_2 years.
Where: L_t**:** fish length (**L**) at fish age (t), t_L**:** fish age **t** at fish length L.

Procuring the raw data for calculating the model parameters

The length-weight relationship and the fish length at age data used in the present study to calculate the components of the von Bertalanffy model parameters (L_∞, W_∞, K and t_0) of *Liza aurata* of Umm Hufayn lagoon were obtained from Elshakh *et al*. (2021) and (2023) studies in order. The length-weight relationship (Elshakh *et al*., 2021), $W = 0.006L^{3.111}$, $R^2 = 0.891$, n = 80, was used to convert L_∞ to corresponding W_∞. The fish length at age data used (Elshakh *et al*., 2021) is shown in Table 1. Aging of the fish was achieved by four techniques: reading annuli on opercula and scales, the length-frequency-distribution of the fish in the studied sample, and the "average" of the three techniques. Both, Elshakh *et al*. (2021) and (2023), used in their studies the same fish sample that was in the present study: eighty *Liza aurata* collected randomly from the artisanal catch of Umm Hufayn lagoon during January and February 2018.

L_∞ and K were estimated by the Ford–Walford method, t_0 by the von Bertalanffy method, and W_∞ from the length-weight relationship of the fish according to Sparre and Venema (1998). The data shown in Table 1 was used for this purpose.

Table 1. Fish length (cm) at age (years) estimated from the opercula, scales, length frequency distribution, and their "average" (source: Elshakh *et al*., 2023).

Age	Opercula	Scales	Length frequency	Average
1	18.8	18.2	18.18	18.39
2	20.87	21.58	21.6	21.35
3	23.18	24	24	23.73
4	26.86	26.06	26	26.31
5	28.4	28.1	28	28.17
6	30	29.9	30	29.97
7	32			32

Estimating L_∞ and K by the Ford–Walford method

First, lengths at age obtained from the opercula, scales, length frequency distribution, and their" average" (Table 1) were sub-grouped into age (t), length at age (L_t) and L_{t+1} as shown in Table 2 for the opercula.

Second, L_t and L_{t+1} were plotted on the X and Y axes, as shown in Fig. 2.

Third, L_∞ and K were obtained from the plot (Fig. 2): $L_\infty = a/(1 - b)$; $K = -(1/\Delta t) \ln b$, where "a" was the intercept, and "b" the slope of the regression line; $\Delta t = 1$, as t was presented in successive years.

Estimation of t_0 by the von Bertalanffy method

First, lengths at age obtained from opercula, scales, length frequency distribution, and their" average" (Table 1) were sub-grouped into age (t), length at age (L_t), and $-\ln(1 - L_t/L_\infty)$, as shown in Table 3 for the opercula.

Second, t, and $-\ln(1 - Lt/L_\infty)$ were plotted on the X and Y axes, as shown in Fig. 3.

Third, t_0 was obtained from the plot: $t_0 = -a/b$, where a was the intercept, and b the slope of the regression line.

L_∞ and K, and t_0, were calculated for the scales (Table 4, Fig. 4, Table, 5, Fig. 5), the length frequency distribution (Table 6, Fig. 6, Table, 7, Fig. 7), and their "average" (Table 8, Fig. 8, Table, 9, Fig. 9) in the same manner.

Table 2. The Ford–Walford tabulation for estimating L_∞ and K based on the length at age obtained from the opercular annuli (Table 1).

T yr	L_t cm	L_{t+1} cm
	X	Y
1	18.8	20.87
2	20.87	23.18
3	23.18	26.86
4	26.86	28.4
5	28.4	30
6	30	32
7	32	

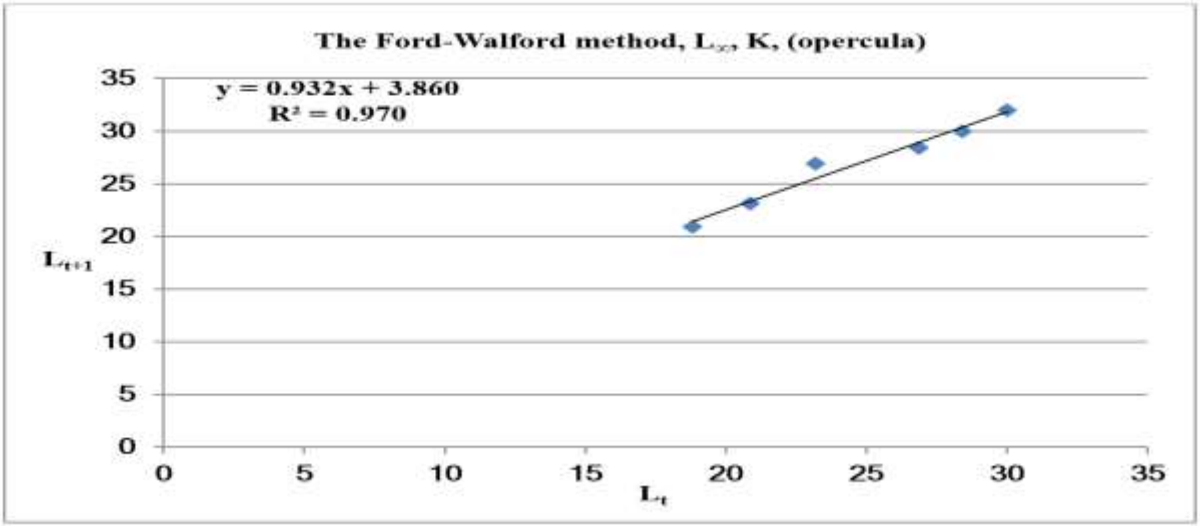

Fig. 2. The Ford–Walford plot for estimating L_∞ and K based on the length at age obtained from the opercular annuli (plot of Table 2).

L_∞ = a/(1 - b) = 3.860/(1-0.932) = 56.765 cm; K = - (1/Δt) ln b = - (1/1) ln 0.932 = 0.070 yr^{-1}

Table 3. The von Bertalanffy tabulation for estimating t_0 based on the length at age obtained from the opercular annuli (Table 1).

t yr	L_t cm	$- \ln (1 - L_t/L_\infty)$
X		Y
1	18.8	0.402255
2	20.87	0.458322
3	23.18	0.52484
4	26.86	0.640894
5	28.4	0.693764
6	30	0.751825
7	32	0.829489

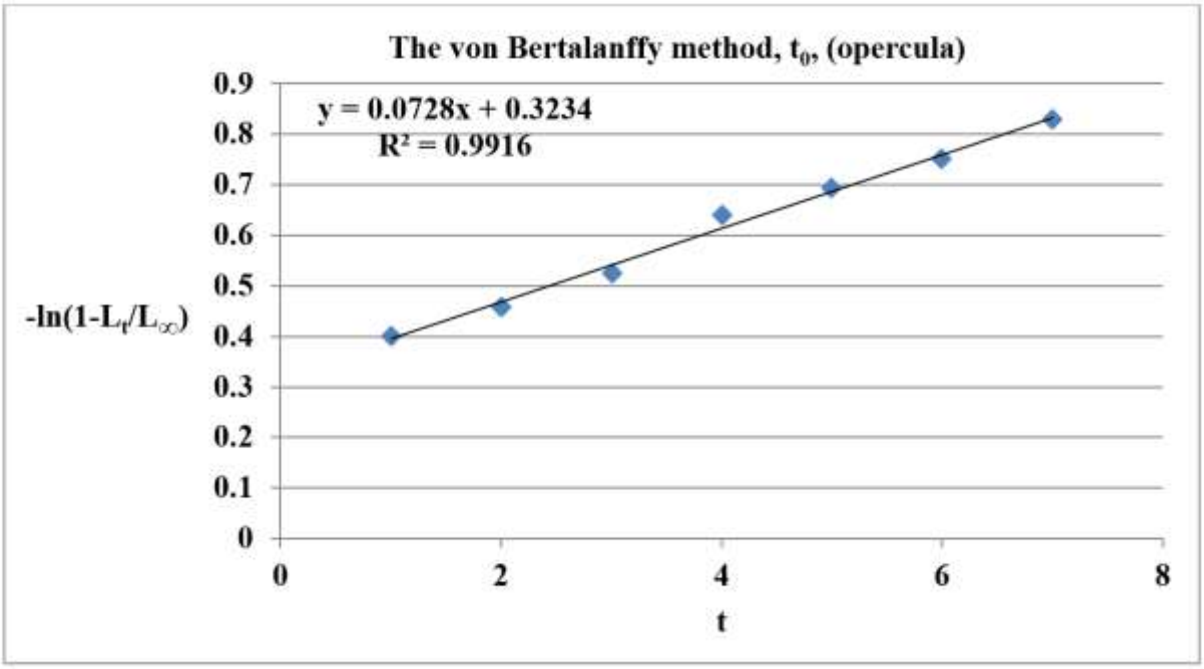

Fig. 3. The von Bertalanffy plot for estimating t_0 based on the length at age obtained from the opercular annuli (plot of Table 3).

$t_0 = -a/b = -0.3234/0.0728 = -4.44$ years.

Table 4. The Ford–Walford tabulation for estimating L_∞ and K based on the length at age obtained from the scale annuli (Table 1).

t yr	L_t cm	L_{t+1} cm
	X	Y
1	18.2	21.58
2	21.58	24
3	24	26.06
4	26.06	28.1
5	28.1	29.9
6	29.9	

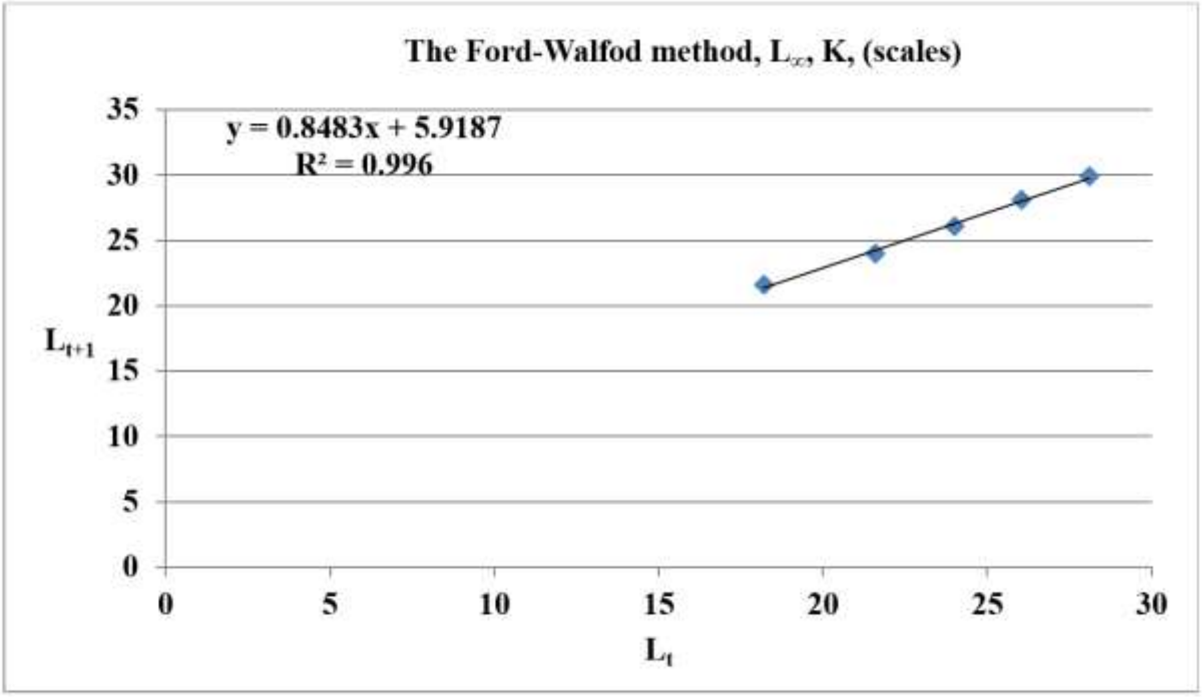

Fig. 4. The Ford–Walford plot for estimating L_∞ and K based on the length at age obtained from the scale annuli (plot of Table 4).

K = - (1/Δt) ln b = - (1/1) ln0.8483 = 0.164 yr^{-1}; L_∞ = a/(1 - b) = 5.918/(10.848) = 39.02 cm.

Table 5. The von Bertalanffy tabulation for estimating t_0 based on the length at age obtained from the scale annuli (Table 1).

t yr	L_t cm	- ln (1 - L_t/L_∞)
X		Y
1	18.2	0.62816
2	21.58	0.805308
3	24	0.954692
4	26.06	1.102207
5	28.1	1.273478
6	29.9	1.453605
7		

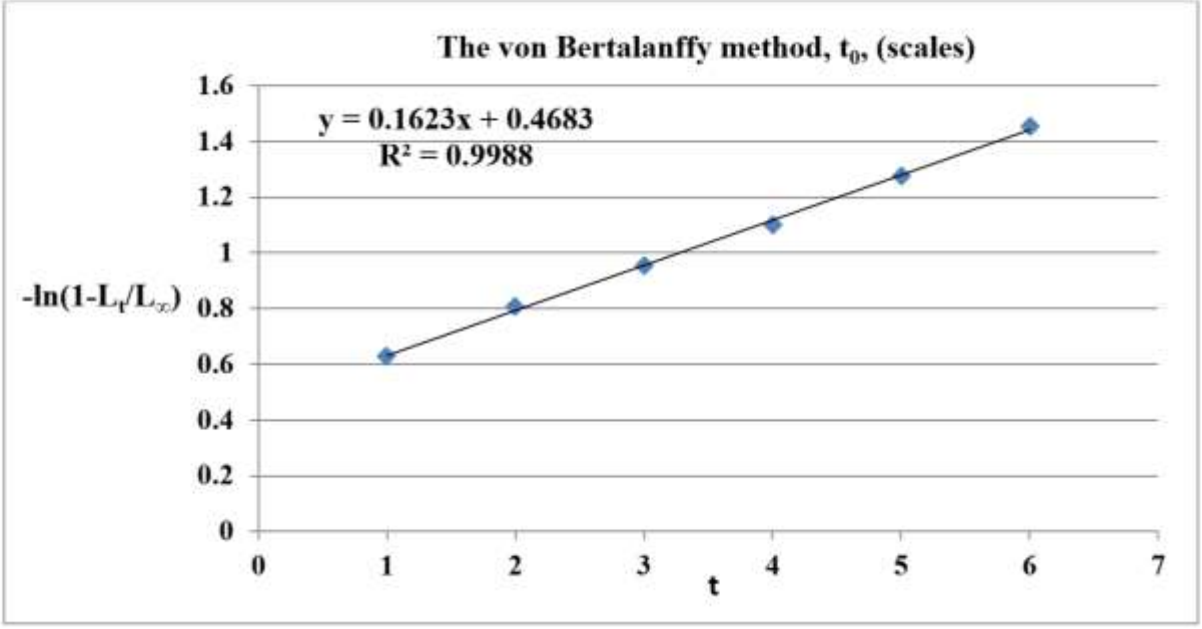

Fig. 5. The von Bertalanffy plot for estimating t_0 based on the length at age obtained from the scale annuli (plot of Table 5).

$t_0 = -a/b = -0.4683 / 0.1623 = -2.8$ years.

Table 6. The Ford–Walford tabulation for estimating L_∞ and K based on the length at age obtained from the length frequency distribution (Table 1).

t yr	L_t cm	L_{t+1} cm
	X	Y
1	18.18	21.6
2	21.6	24
3	24	26
4	26	28
5	28	30
6	30	

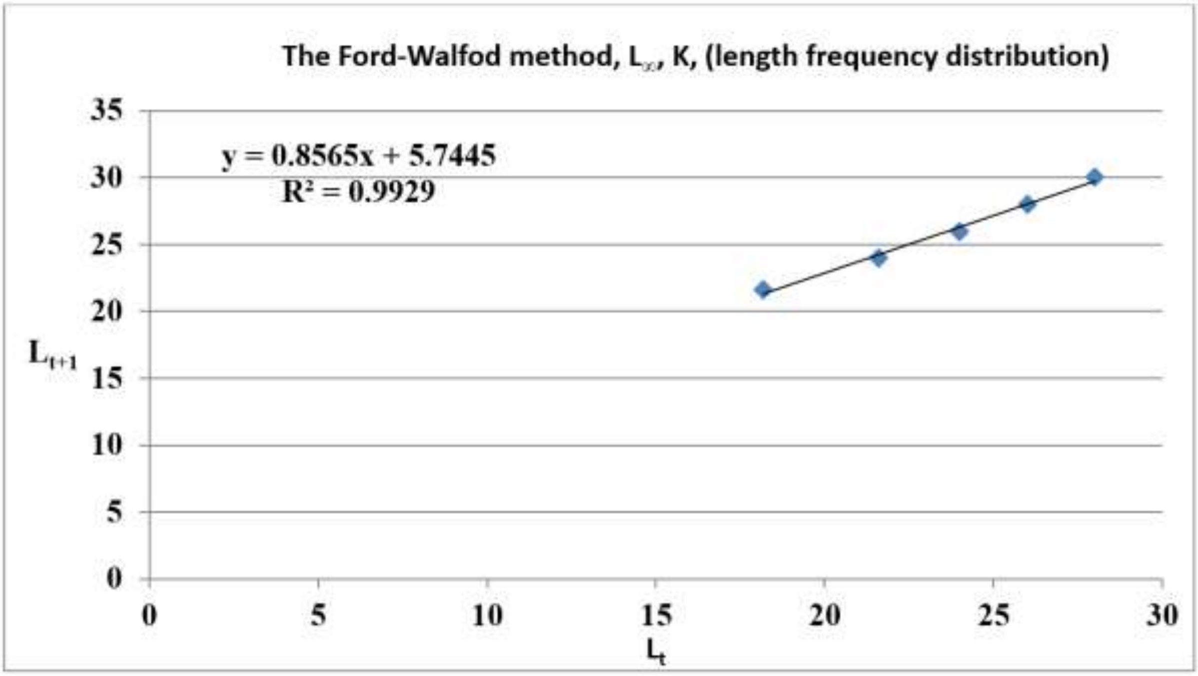

Fig. 6. The Ford–Walford plot for estimating L_∞ and K based on the length at age obtained from the length frequency distribution (plot of Table 6).

$L_\infty = a/(1 - b) = 5.7445/(1-0.8565) = 40.0$ cm; $K = - (1/\Delta t) \ln b = - (1/1) \ln 0.856 = 0.155$ yr^{-1}

Table 7. The von Bertalanffy tabulation for estimating t_0 based on the length at age obtained from the length frequency distribution (Table 1).

t yr	L_t cm	$- \ln (1 - L_t/L_\infty)$
X		Y
1	18.18	0.6054
2	21.6	0.7756
3	24	0.9151
4	26	1.0484
5	28	1.2022
6	30	1.3839
7		

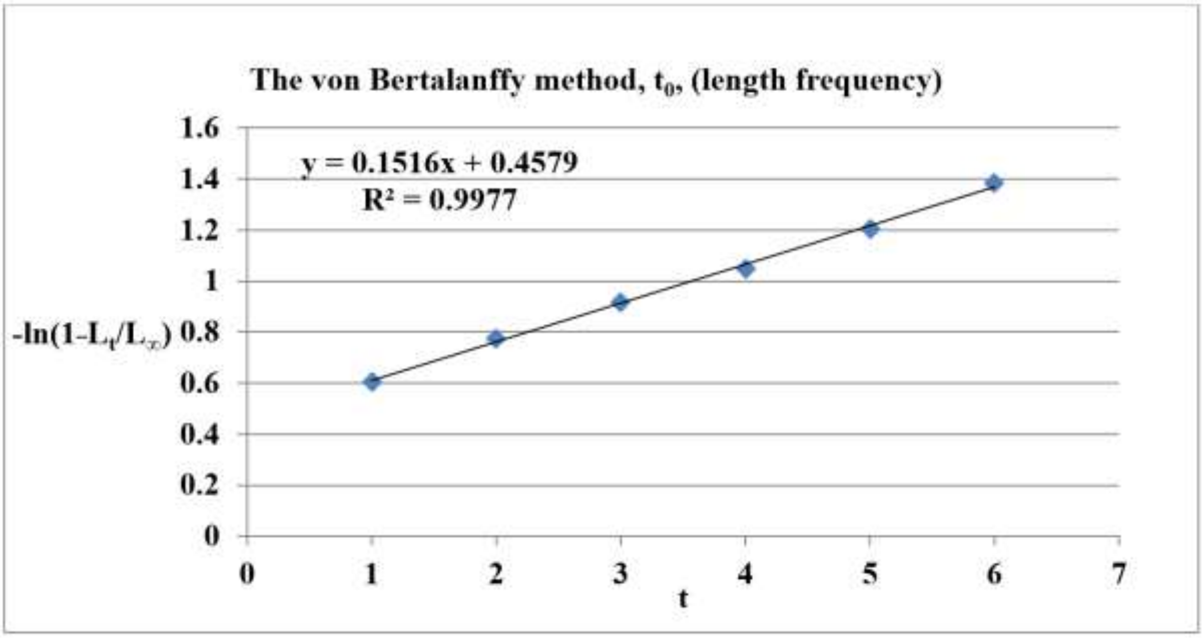

Fig. 7. The von Bertalanffy plot for estimating t_0 based on the length at age obtained from the length frequency distribution (plot of Table 7).

$t_0 = -a/b = -0.4579/0.1516 = -3.0204$years.

Table 8. The Ford–Walford tabulation for estimating L_∞ and K based on the length at age obtained from the "Average" (Table 1).

t yr	L_t cm	L_{t+1} cm
	X	Y
1	18.393	21.35
2	21.35	23.727
3	23.727	26.307
4	26.307	28.167
5	28.167	29.9667
6	29.967	32
7	32	

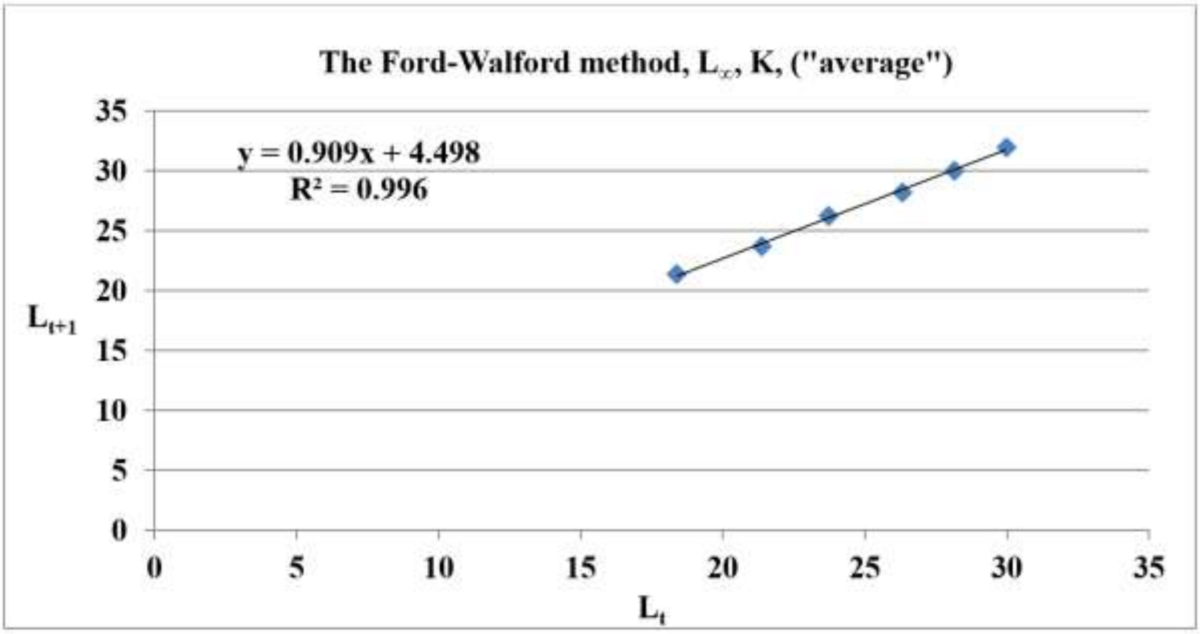

Fig. 8. The Ford–Walford plot for estimating L_∞ and K based on the length at age obtained from the "Average" (plot of Table 8).

L_∞ = a/(1 - b) = 4.498/(1-0.909) =49.705 cm; K = - (1/Δt) ln b = - (1/1) ln 0.909= 0.0949 yr^{-1}

Table 9. The von Bertalanffy tabulation for estimating t_0 based on the length at age obtained from the "average" (Table 1).

t yr	L_t cm	- ln (1 - L_t/L_∞)
X		Y
1	18.39	0.46
2	21.35	0.56
3	23.73	0.65
4	26.31	0.75
5	28.17	0.84
6	29.97	0.92
7	32	1.03

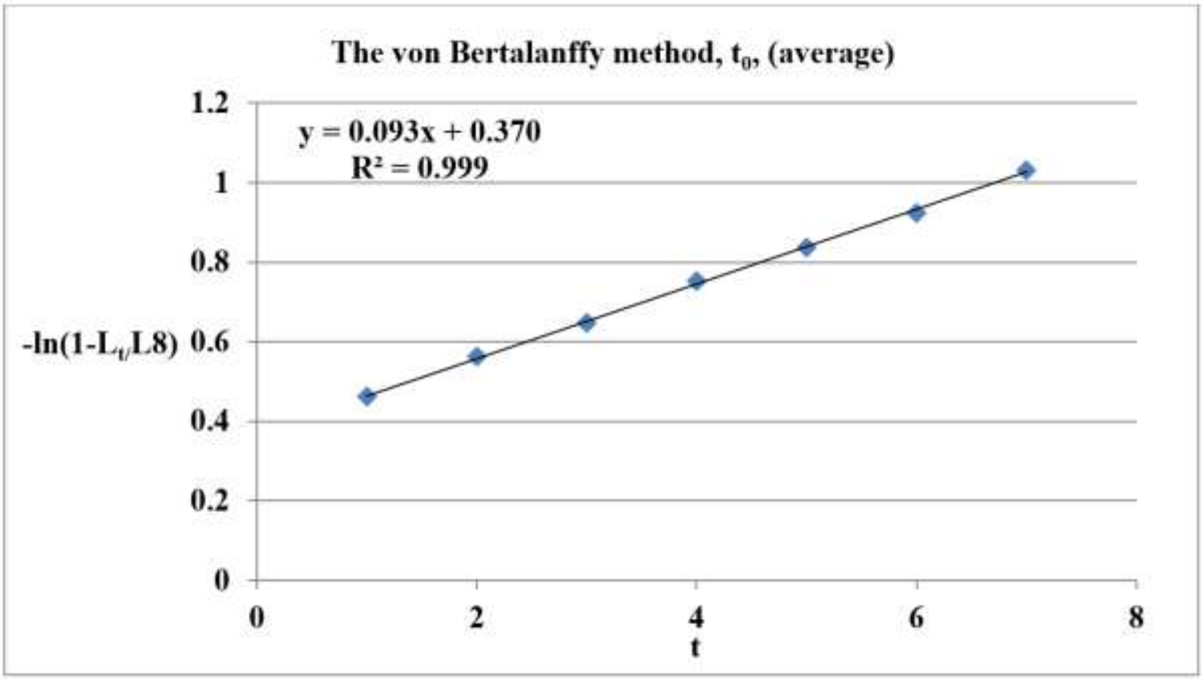

Fig. 9. The von Bertalanffy plot for estimating t_0 based on the length at age obtained from the "average" (plot of Table 9).

t_0 = -a/b = - 0.370/0.093 = - 3.9573 years

Calculating W_∞

W_∞ was calculated by substituting the values of L_∞ presented in Table 10 (in the results section) in L of the following power length-weight relationship developed for *L. aurata* of the present study by Elshakh *et al*. (2021). The obtained corresponding W_∞ values are presented in the same table (Table 10):

$W=0.006\ L^{3.111}$, R^2: 0.891… (Elshakh *et al*., 2021)

Calculating the growth performance index $Ø^/$ for the established von Bertalanffy growth models

Growth is a non-linear process that cannot be described by a single parameter, but rather by multiple parameters that work together. In the von Bertalanffy model, the parameters are L_∞, K, and t_0. Therefore, Munro's growth performance index, $Ø^/$, which takes into account K and L_∞, was used to compare the established models with each other (Pauly, 1984; Munro and Pauly, 1983; Pauly and Munro, 1984): $Ø^/ = \log_{10} K + 2 \log_{10} L_\infty$.

RESULTS

The size of the study fish

The mean length (± SD) of mixed female/male *L. aurata* was 21.331± 3.010 cm corresponding to a mean weight of 89.011±52.724g.

The von Bertalanffy growth model established for *L. aurata*

The von Bertalanffy parameters calculated for *L. aurata* are presented in Table 10. Length at age based on the opercula, scales, length frequency distribution, and their means are presented in Table 10. Ø/ values were close, ranging from 2.3532 to 2.4249. The complete von Bertalanffy growth models based on their parameters are shown in Table 11.

Table 10. The von Bertalanffy growth-model parameters calculated for *L. aurata*

von Bertal. parameters	Opercula	Scales	Length frequency	Average	Mean parameters
L_∞ cm	56.76	39.02	40.03	49.70	45.27
K yr^{-1}	0.07	0.16	0.15	0.09	0.13
t_0 yr	-4.44	-2.8	-3.02	-3.96	-3.42
Ø/	2.35	2.4	2.39	2.37	2.42
W_∞ g	1718.29	535.36	579.72	1136.71	849.94cv

Table 11. The von Bertalanffy growth models established by entering calculated values of L_∞, W_∞, K, and t_0 in the model equations (Table 10).

von Bertalanffy model equations	$L_t = L_\infty *\{1 - \exp(-K*(t-t_0))\}$ cm $W_t = W_\infty *\{1 - \exp(-K*(t-t_0)\}^b$ g $t_L = t_0 - 1/K*\ln(1 - L/L_\infty)$ yr $\Delta t = t_2 - t_1 = (1/K) \ln((L_\infty - L_1)/(L_\infty - L_2))$ yr
Opercula	$L_t = 56.765*(1-\exp(-0.070*(t+4.440)))$ $W_t = 1718.289*[1-\exp(-0.070*(t+4.440))]$^3.111 $t_L = -4.440-1/0.070*\ln(1-L/56.77)$ $\Delta t = (1/0.070) \ln((56.765-L_1)/(56.765-L_2))$
Scales	$L_t = 39.02*(1-\exp(-0.1645*(t+2.8)))$ $W_t = 535.36*[1-\exp(-0.1645*(t+2.8))]$^3.111 $t_L = -2.8-1/0.1645*\ln(1-L/39.02)$ $t\Delta = (1/0.1645) \ln((39.02-L_1)/(39.02-L_2))$
Length Frequency distribution	$L_t = 40.0313*(1-\exp(-0.1549*(t+3.0204)))$ $W_t = 579.7179*[1\exp(0.1549*(t+3.0204))]$^3.111 $t_L = -3.0204-1/0.1549*\ln(1-L/40.313)$ $\Delta t = (1/0.1549) \ln((40.0313-L_1)/(40.0313-L_2))$
Average	$L_t = 49.7049*(1-\exp(-0.0949*(t+3.9573)))$ $W_t = 1136.709*[1\exp(0.0949*(t+3.9573))]$^3.111 $t_L = -3.9573-1/0.949*\ln(1-L/49.7049)$ $\Delta t = (1/0.949) \ln((49.7049-L_1)/(49.7049-L_2))$
Mean Model parameters	$L_t = 45.2704*(1-\exp(-0.1298*(t+3.42)))$ $W_t = 849.9427*[1-\exp(-0.1298*(t+3.42))]$^3.111 $t_L = -3.42-1/0.1298*\ln(1-L/45.2704)$ $\Delta t = (1/0.1298) \ln((45.2704-L_1)/(45.2704-L_2))$

Predictability of the established von Bertalanffy models

All the established models (Table 11) showed a high degree of predictability. The length-at-age values predicted by the individual models were close to the measured values (Table 12). However, even though the predicted values almost overlapped the measured values in mutual plots (Figs 10 to 14), significant differences were observed at high ages, e.g., 30 years (Table 12). The $Ø^/$ values calculated for all the established models were close (Table 10).

Table 12. Measured (Me) and predicted (Pr) lengths-at-age (cm)

Age	Mean length at age (cm)								
	Opercula		Scales		Length frequency		Average		*M. param.
	Me	Pr	Me	Pr	Me	Pr	Me	Pr	Pr
1	18.8	17.975	18.2	18.136	18.2	18.556	18.39	18.6531	19.6735
2	20.87	20.597	21.58	21.304	21.6	21.638	21.35	21.4644	22.7713
3	23.18	23.042	24	23.991	24	24.277	23.73	24.0212	25.4943
4	26.86	25.321	26.06	26.271	26	26.538	26.31	26.3465	27.8877
5	28.4	27.447	28.1	28.205	28	28.474	28.17	28.4613	29.9915
6	30	29.429	29.9	29.845	30	30.133	29.97	30.3846	31.8406
7	32	31.276		31.237		31.553	32	32.1338	33.4659
8		32.999		32.417		32.77		33.7246	34.8946
9		34.606		33.419		33.812		35.1714	36.1504
10		36.103		34.268		34.704		36.4872	37.2541
12		38.802		35.601		36.123		38.7722	39.0771
14		41.148		36.559		37.165		40.6622	40.4855
16		43.188		37.249		37.928		42.2255	41.5736
18		44.961		37.746		38.488		43.5185	42.4143
20		46.502		38.103		38.899		44.5879	43.0638
25		49.532		38.617		39.51		46.5212	44.1127
30		51.666		38.843		39.791		47.7239	44.6629

*M. param.: Mean parameter (of Pr of opercula, scales, length frequency and average).

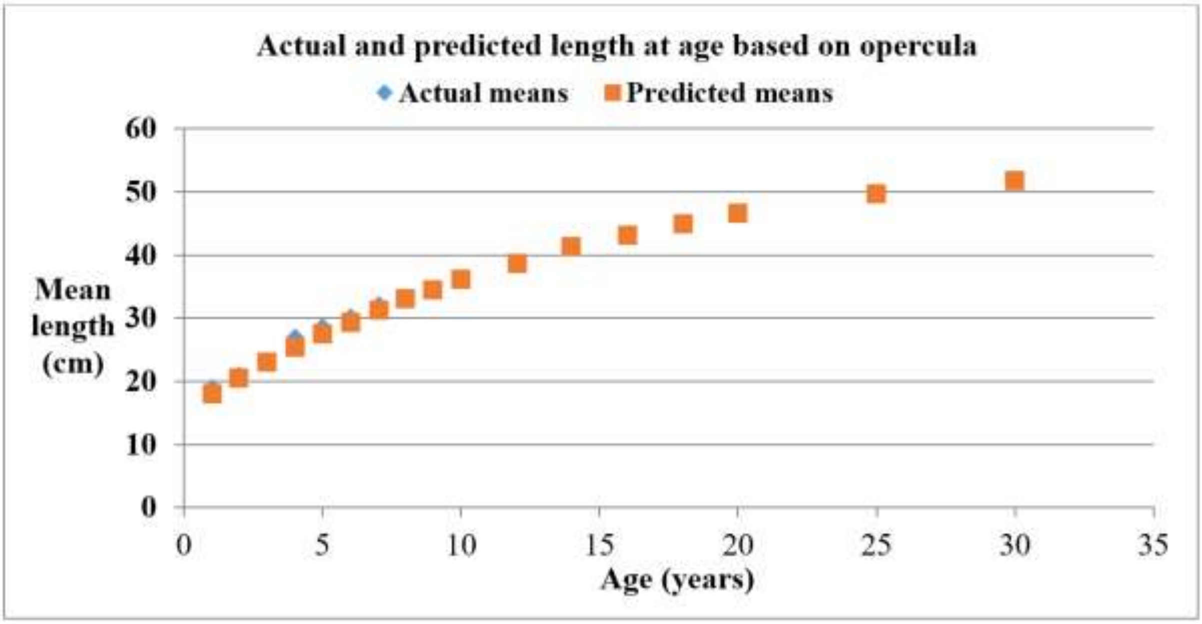

Fig. 10. Plot of the measured (actual) and predicted length at age values "$L_t = 56.765*(1-\exp(-0.070*(t+4.440)))$ cm based on the opercula" (values apparently completely overlapped).

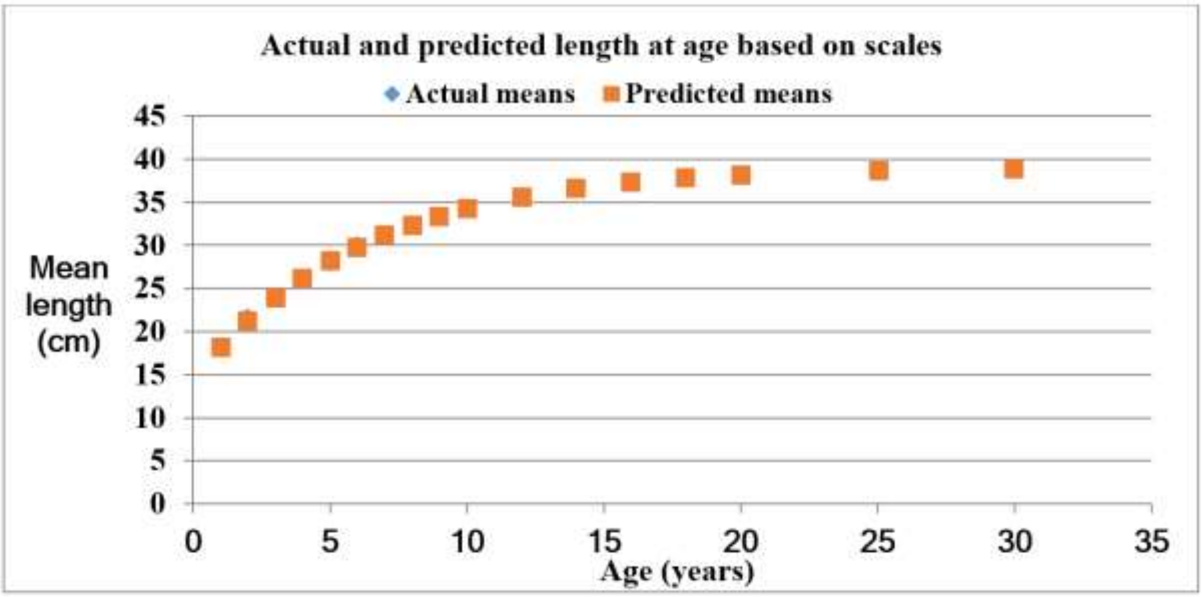

Fig. 11. Plot of the measured (actual) and predicted length at age values "$L_t = 39.02*(1-\exp(-0.1645*(t+2.8)))$ cm based on the scales" (values almost completely overlapped).

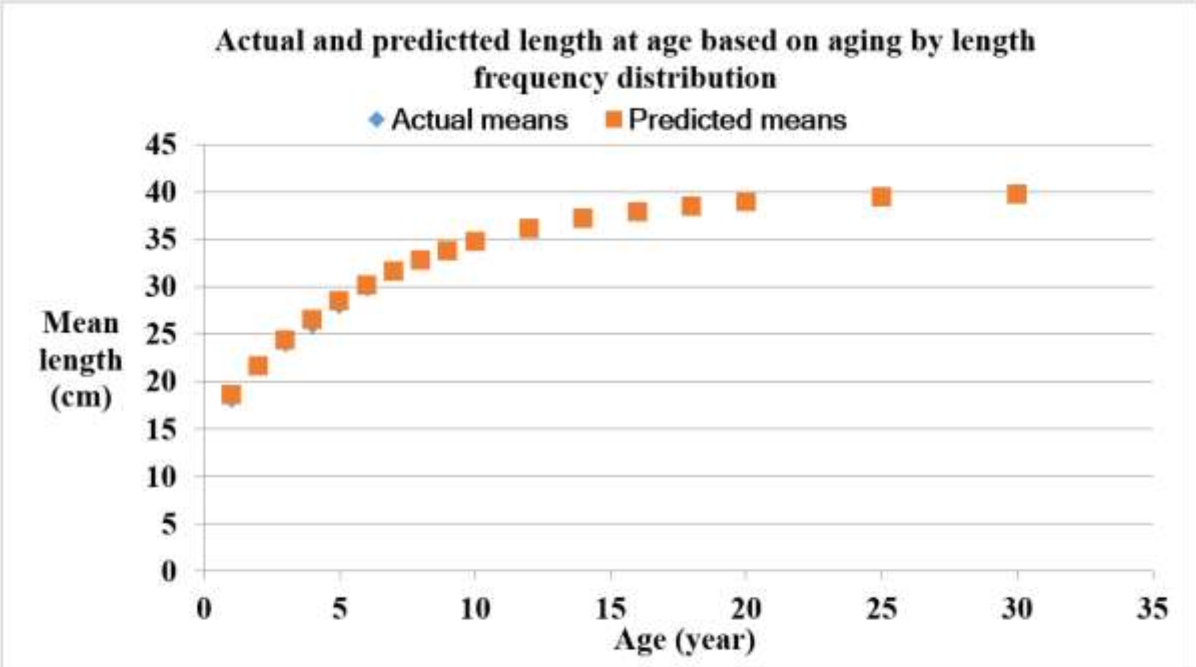

Fig. 12. Plot of the measured (actual) and predicted length at age values "L_t = 40.0313*(1-exp(-0.1549*(t+3.0204))) cm based on the length frequency distribution" (values almost completely overlapped).

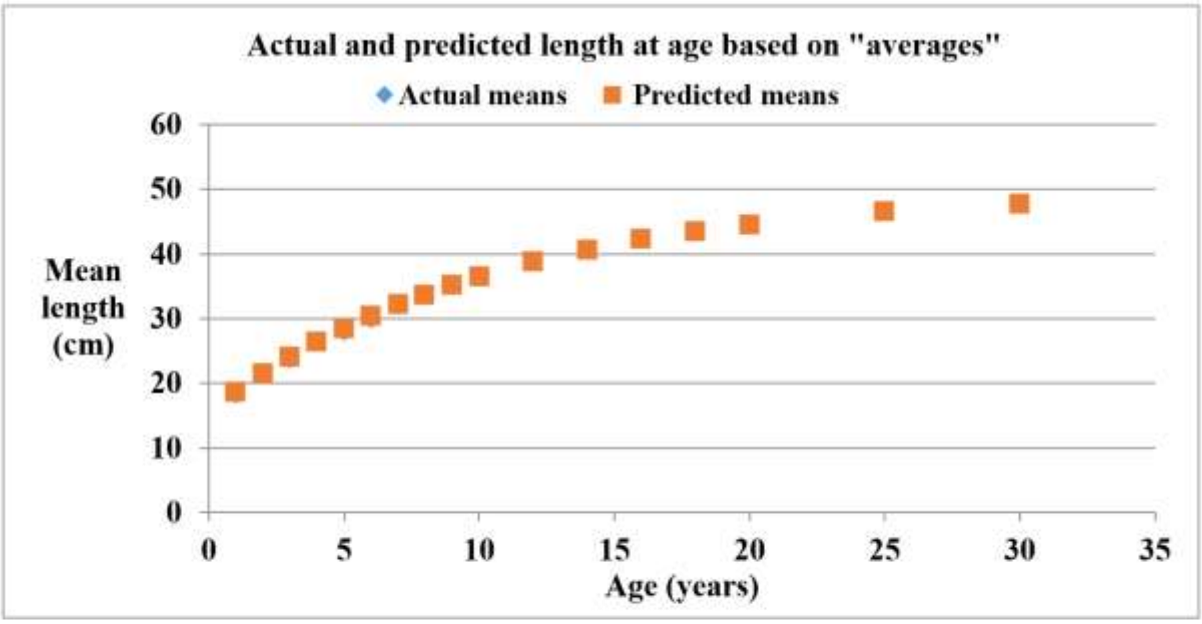

Fig. 13. Plot of the measured (actual) and predicted length at age values "L_t = 49.7049*(1-exp(-0.0949*(t+3.9573))) cm based on the "average" (values almost completely overlapped).

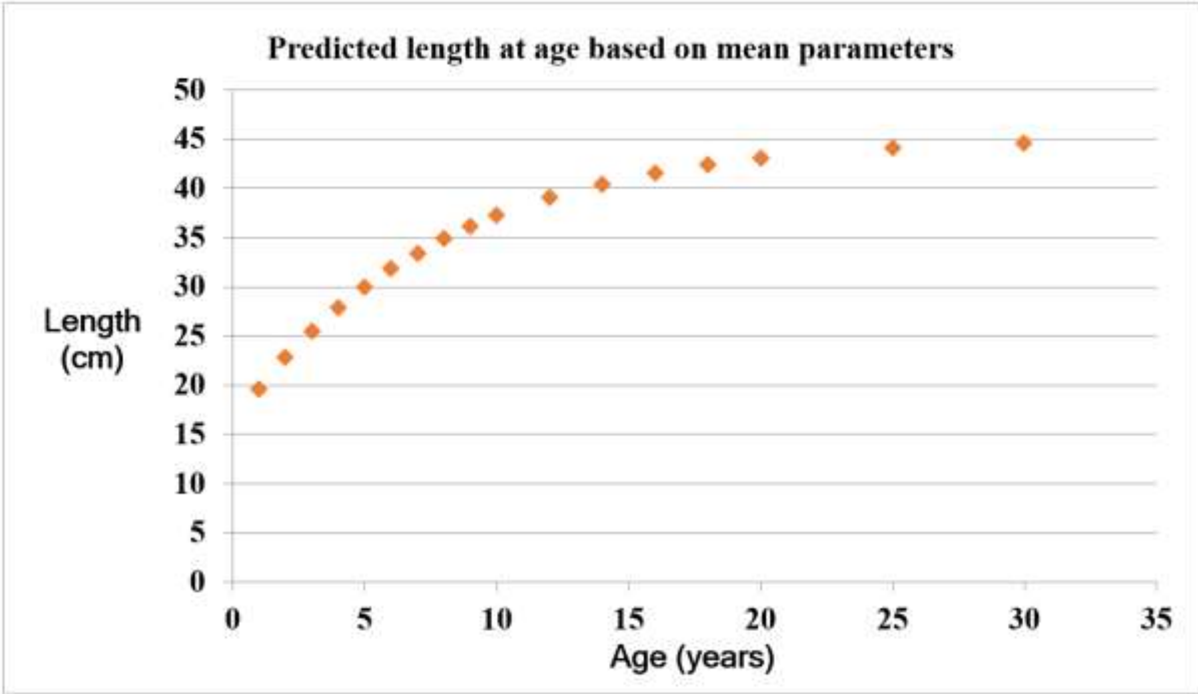

Fig. 14. Plot of the predicted length at age values "L_t = 45.2704*(1-exp(-0.1298*(t+3.42))) cm based on the 'mean-model parameters'".

DISCUSSION

In the present study, four methods were used to establish the mean length-at-age of *L. aurata*: counting annuli on opercula and scales, the length frequency distribution, and the "averages" of these methods (See Elshakh, *et al.*, 2021 for further details). The values of length at age obtained by these methods were not very close. Reading the annuli on sagittae failed because of opacity. Further, reading the annuli on the opercula and scales was also not easy, and the degree of uncertainty was not low, even when many scales for the same fish were examined. However, a few previous studies have shown that annuli can be read on the sagittae of tropical fish (whole or sectioned), but this is not general for all species or the same species in different habitats. The problem of indistinct annual growth rings on hard parts of tropical fish was discussed by many authors. Annual rings are formed on hard parts of fish due to different growth rates in the worm and cold seasons in response to changes in the prevailing habitat parameters, such as temperature, and availability of food (Ricker, 1975). In tropical regions, drastic changes do not occur, and, hence, the annual growth rings are not as distinct as in the temperate regions (Gallucci *et al.*, 1996; Sperre and Venema, 1998). Abd el Rahman and Moghraby (1984) and Sparre and Venema (1998) suggested the use of more than one method for aging tropical fish. The present study concludes that the length frequency distribution might be a better choice for aging tropical fish with indistinct growth rings provided that a large sample in which young and old fish are well represented is used, the fish must have a distinct and short spawning season; this is also true for annuli reading. In the present study, the 80 fish samples used were found to constitute seven cohorts. The other methods, such as counting daily growth rings (Vincent *et al*., 1996) and capture-recapture, are of limited use. Recording the growth of cultured fish yields accurate information, but most fish are cultured only for one or two years.

In the present study, the von Bertalanffy parameters calculated from the fish length-at-age obtained through the various aging methods used were not close. L_∞ ranged from 39.02 to 56.76 cm, W_∞ from 535.36 to 1718.29 g, K from 0.07 to 0.164 yr^{-1}, and t_0 from -2.8 to -4.44 years. However, even though the individual sets of parameters (L_∞, K, and t_0) obtained by the different methods were not similar, the models derived from them described a similar growth pattern; that is to say, the lengths at age predicted by these models were close to the measured values even though the parameters comprising them were more or less different. Further, the magnitudes of the growth performance index, Ø/, of these models were very close. This is because the von Bertalanffy model is a non-linear, multi-parametric equation. Sparre and Venema (1998) alerted that when comparing different estimates of the von Bertalanffy model the comparison should not be based solely on the magnitudes of the individual parameters (values of the L_∞, K, and t_0 of each model) but on the growth pattern predicted by their mutual expression. Sparre and Venema (1998) also stressed that the values of these parameters, though collectively describing growth patterns satisfactorily, become of physiological importance only when large, unbiased samples are used in their estimation. The values of our L_∞, W_∞, and K obtained in the present study were comparable to those reported in the literature for *L. aurata,* but our t_0 is high. Some of the parameters of *L. aurata* in various parts of the Adriatic Sea, Mediterranean Sea, Black Sea, Atlantic Ocean, and Aegean Sea were presented by Ilkyaz *et al*. (2006) and Kraljević *et al*. (2011); in Homa Lagoon, Izmir Bay, Aegean Sea, the parameters were L_∞ = 43.2 cm, K = 0.33 yr^{-1}, and t_o = –0.30 year. In the same Sea, Kraljević *et al*. (2011) reported L_∞ = 40.0 cm, K = 0.214 yr^{-1}, $t_ө$ = -1.150 year; W_∞ = 606 g, K = 0.162 yr^{-1}, and t_o =-1.962 year. In the Messolonghi-Etoliko Lagoon and the adjacent Gulf of Patraikos, Western Greece, the values were L_∞ = 65.08±2.61 cm; k = 0.149±0.017 yr^1, and t_o = –1.15 ± 0.063 year (Hotos and Katselis, 2011). In Tunisia, the model was $L_t = 364\ (1-e^{-\ 0.180\ (t\ +\ 1.810)})$ and $L_t = 397\ (1\ -e^{-\ 0.164\ (t\ +\ 1.513)})$, t_o was -1.810 and -1.513, in order (Fehri-Bedoui and Gharbi, 2015); and $L_t = 38.51[1-e^{-0.2421(t+1.4222)}]$ and $W_t = 491.96\ [1-e^{-0.2421(t+1.4222)}]^{3.053}$ in Egypt (Mrizek, *et al*., 2021).

REFERENCES

Abd el Rahman, A. and A. I. Moghraby. (1984). Use of the frontal bone in age determination of *Labeo horie* (Pisces, Cyprinidae) in Jebel Aulia Reservoir, Sudan in (Hydro biological Research unit, Faculty of Science, University of Khartoum. Sudan.

Bardach, J. E; Ryther, J. H. and Mclarney, w. O. (1972). 1 Aquaculture; the farming and husbandry of freshwater and marine organisms. Wiley inter science, New York.

Elshakh, Alia Salem; Ramadan A. S. Ali; Sayed Mohamed Ali; Najia S. Hussain. (2021). Some morphometric traits of *Liza aurata* (Risso, 1810) in Umm Hufayn brackish lagoon, eastern Libya Mediterranean Sea coast. International Journal of Fisheries and

Aquaculture Research Vol.7, No.1, pp.11-27, January 2021 Published by ECRTD-UK ISSN: ISSN 2397-7507, Online ISSN: ISSN 2397-776.

Elshakh, Alia Salem; Sayed Mohamed Ali; Ramadan A. S. Ali. (2023). Some biological and fisheries indicators of the golden gray mullet, *Liza aurata* (Mugilidae) in the southern Mediterranean coast (Libya). Under publication.

Elzey, S. P., Katie A. Rogers and Kimberly J. Trull. (2015). Comparison of 4 aging structures in the American shad (*Alosa sapidissima*) Fish. Bull. 113:47–54 (2015). doi: 10.7755/FB.113.1.5

Fehri-Bedoui, Rafika and Houcine Gharbi. (2015). Âge et croissance de *Liza aurata* (Mugilidae) des côtes tunisiennes. Cybium 2005, 29(2): 119-126.

Gallucci, F. V. Saila, B. S. Gustafson, J. D. and Rothschild, J. B. 1996. Stock Assessment quantitative methods and applications for small-scale fisheries. United States of America. pp. 224.

Gulland J. A. (1983). Fish stock assessment. A manual of basic methods. FAO/Wiley series on Food and Agriculture 1: 223.

Gulland, J. A. (1985). Fish stock Assessment. A manual of basic methods. Marine resources service. Rome, Italy, p. 293.

Hile, R. (1941). Age and growth of the rock bass, *Amloloplites rupestris* (Rafinesque) in Nebish lake, Wisconsin. Trans. Wis. Acad. Sci. lett., 33: 189-337.

Hotos G. N., Katselis G. N. (2011). Age and growth of the golden grey mullet *Liza aurata* (Actinopterygii: Mugiliformes: Mugilidae), in the Messolonghi-Etoliko Lagoon and the adjacent Gulf of Patraikos, Western Greece. Acta Ichthyol. Piscat. 41 (3): 147–157

İlkyaz, Akin Türker; Firat, Kürşat; Saka, Şahin; and Kinacigil, Hasan Tuncay. (2006). "Age, Growth, and Sex Ratio of Golden Grey Mullet, *Liza aurata* (Risso, 1810) in Homa Lagoon (İzmir Bay, Aegean Sea)," Turkish Journal of Zoology: Vol. 30: No. 3, Article 7.

Kraljević, Miro; Jakov Dulčić; Armin Pallaoro; Sanja Matić-Skoko. (2011). Age and growth determination of the golden grey mullet, *Liza aurata* (Risso, 1810) from the Adriatic Sea by using scale readings and length frequency analysis. ACTAADRIAT., 52(2): 223 - 234, 2011

Mrizek, Tamer; Gaber D. Ibrahim; M. S. Ahmed and Attia A. Omar. (2021). Some biological aspects of golden grey mullet, *Liza aurata* (Risso, 1810) from Bardawil Lagoon, Egypt. Sini Journal of Applied Sciences. Volume 10, Issue 2. August 2021. Pages 161-174.

Munro, J. L. and D. Pauly. (1983). A simple method for comparing the growth of fishes and invertebrates. Fishbyte, 1(1): 5-6.

Pauly, D. (1984). Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Stud. Rev., 8: 325 p.

Pauly, D. amd J. L. Munro. 1984. Once more on the comparison of growth in fishes and invertebrates. Fishbyte, 2(1): 21.

Pauly, D. and G. R. Morgan,1987. Length-based methods in fisheries research. ICLARM Conf. proc. (13): 468 p.

Reynolds, J. E., Haddoud, D. A., Vallet, F., (1995). Prospects for aquaculture development in Libya, Libfish Field Document No 9. Tripoli / Rome, FAO.

Ricker, W. E. (1975). Interpretation of biological statistics of fish populations, Department of the Environment Fisheries and Marine Service Pacific Biological Station, Nanaimo, B. C. V 9R5 K6, pp. 266.

Sparre, Per and Venema, S. C., (1998). Introduction to tropical fish stock assessment. Part one, Manual. FAO Fisheries Technical paper, 306. Rome, Italy. PP. 376.

Talwar, P. K., Jhingran A. G. (1992). Inland fishes of India. Rec. Ind. J., 3: 19-24.

Tesch, F. W. (1968). Age and water growth. In Ricker, W. E. (ed), Methods for assessment of fish production in fresh. IBPH and book No. 3, Blackwell, London.

Tuset, V. M., A. Lombarte, J. A. Gonzalez, J. F. Pertusa and M. J. Lorente. (2003). Comparative morphology of the sagittal otolith in Serranus spp. Journal of fish biology (2003)63, 1491-1504.

Vincent, F. S.; Gallucci, B.; Gustafson, J. and Rothschild, J (1996). Stock assessment quantitative methods and application for small scale fisheries, USA.

von Bertalanffy L. Von. (1934). Untersuchungenuber die Gesetzlichkeiten des Wachstums. 1. Allgemeine Grundlagender Theorie. Roux' Arch. Entwicklungsmech. Org., 131: 613-53.