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Environmental Pollution and Challenges of Environmental Sustainability (EPESC),
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Some Growth Traits of the Atlantic Lizardfish *Synodus Saurus* in The Southern Mediterranean Sea

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***Abstract**: This* study aimed to determine the growth traits of the Atlantic lizardfish (*Synodus saurus*) in the Southern Mediterranean Sea (Benghazi, eastern Libya). The von Bertalanffy growth model parameters were derived from length-at-age data obtained by reading growth annuli on scales (Sc) from a sample of 70 fish, from the length-frequency-distribution (LFD) of a random sample of 600 fish, and by the Solver statistics (So). In both Sc and LFD methods, the constants L_∞ and k, and t_0 were estimated using the Walford, and the von Bertalanffy methods, respectively. Total mortality (Z) was calculated using the linearized catch curve, natural mortality (M) was estimated using Pauly's empirical formula, and the fishing mortality (F) was determined by subtraction. The mean total length (TL) of the fish was 20.14 cm, with a corresponding mean weight (TW) of 66.93 gm. The ratio of head length to total length was 0.223. The von Bertalanffy constants, as calculated from Sc, LFD, and So methods, respectively, were L_∞: 46.99, 45.03, 48.23 cm; k: 0.094, 0.1105, 0.092 year^{-1}; t_0: -2.5944, -1. 697, -2.7101 year. The growth performance index (Ø/) values were 2.317, 2.350, 2.330, respectively. The growth models derived from these methods (Sc, LFD, So) showed high reliability, the lengths-at-age predicted were close to the observed values. The residuals of the three methods were analyzed and compared. In addition to TL, TW, and head length-to-TL ratio, key fisheries-related parameters included total mortality (Z) "0.7286 year^{-1}", fishing mortality (F) "0.368 year^{-1}" and the survival rate (S) "0.4826" calculated from LFD, and the following parameters calculated from Sc, LFD, So, consecutively: natural mortality (M): 0.3208, 0.3609, 0.314 year^{-1}; Length-at first maturity (L_m): 12.23, 11.78, 12.51 cm; Length at optimum yield (L_{opt}): 21.98, 21.56, 22.82 cm. The exploitation ratio

(E) of 0.50 suggested that the fishery was operating at an optimal level, though certain precautions are warranted. For instance, the calculated L_{opt} of 21.56 to 22.89 cm exceeded the mean catch length, TL (20.14±.42 cm), which is a warning sign. However, the length at first maturity, L_m (11.78 to 12.51 cm), was lower than TL, which is a positive indication.

Introduction

Synodus saurus, or the Atlantic lizardfish, (Synodontidae) is recognized for its elongated body and sharp teeth suited for predation. It inhabits tropical and subtropical coastal waters, ranging from the Mediterranean Sea to the North Atlantic Ocean and West African coasts, typically at sandy and muddy shallow bottoms, and up to 400 meters. As a predator, *Synodus saurus* plays a key role in maintaining marine ecosystem balance by preying on small fish and invertebrates (Ismen *et al*., 2004; Tsikliras & Koutrakis, 2011). Though not a primary target species, *Synodus saurus* is commonly caught as bycatch in Libyan artisanal fisheries, where it is sold locally.

Several models describe individual and population growth, including the Von Bertalanffy, Logistic, Gompertz, and Richards models. The **von Bertalanffy Growth Model** is particularly prevalent in fisheries science due to its realistic depiction of growth deceleration as an organism age, with rapid growth in youth and slower growth nearing maturity (Ismen *et al*., 2004; Bilecenoglu & Kaya, 2002; Tsikliras & Koutrakis, 2011; Keskin & Duzgunes, 2008):

$$\mathbf{L_t = L_\infty *\{(l - \exp(-K*(t-t_0))\}}$$

Where: **L(t)**: the length of the organism at age **t**; $\mathbf{L_\infty}$: the asymptotic length (the maximum size the organism can reach); **K**: the growth coefficient, describing the rate at which the organism approaches $\mathbf{L_\infty}$, $\mathbf{t_0}$: the theoretical age at which the organism would have zero length.

Total (Z), **natural (M)**, and **fishing (F)** mortality rates are essential in assessing sustainable fishing practices. These rates help calculate the **exploitation ratio (E)**, which is compared to the optimal reference value (typically 0.5) to maximize sustainable yield. **Survival rate (S)** informs population dynamics and recruitment estimates, where high survival indicates stability and low rates suggest overfishing or environmental stress (Tsikliras & Koutrakis, 2011; Ismen *et al*., 2004). **Length at first maturity ($\mathbf{L_m}$)** ensures fish reproduce before being caught, supporting stock sustainability. It is used to set minimum landing sizes, preventing the capture of juveniles and aiding in population replenishment (Tsikliras & Koutrakis, 2011; Derbal *et al*., 2007; Keskin & Duzgunes, 2008). **Length at optimum yield ($\mathbf{L_{opt}}$)** represents the size at which fish provide the greatest contribution to sustainable yields, balancing growth and reproductive output (Ismen *et al*., 2004; Tsikliras & Koutrakis, 2011).

The aim of the present work was to establish the **Bertalanffy Growth Model, Z, M, F, E, S, $\mathbf{L_m}$,** and $\mathbf{L_{opt}}$ for *Synodus saurus* in the Southern Mediterranean Sea coast (Benghazi, eastern Libya).

Methods

The study sites

The *Synodus saurus* specimens used in this study were obtained from the coastal waters around Benghazi (Juliana Port and nearby areas, 32°36' N, 20°03' E) in eastern Libya (Fig. 1). Benghazi, Libya's second-largest city, is an important deep-sea harbor and industrial center. The coastal area is characterized by small seasonal estuaries, lagoons, wetlands, and brackish tidal marshes, all of which support rich biodiversity. Nearby, the Benghazi Natural Reserve encompasses both marine and terrestrial ecosystems. Benghazi also serves as a key fish landing site and hosts a large fish market (Reynolds *et al*., 1995).

Fig. 1. Benghazi, from which the *Synodus saurus* samples were collected.

The von Bertalanffy growth model

The parameters of the model were derived from length-at-age data obtained from counting growth annuli on scales (Sc) of a sample of 70 fish, the length-frequency-distribution (LFD) of a random sample of 600 fish, and the Solver statistics (So). In both Sc and LFD methods, the constants L_∞ and k, and t_0 were estimated using the Ford-Walford, and the von Bertalanffy methods, respectively.

Aging *Synodus saurus* from counting annular growth rings seen on scales

Seventy fish sample collected randomly from the artisanal catch of Benghazi fishing ground were used for the aging according to Hile (1941); and Tesch (1968). The total length and weight of each fish was recorded before taking the scales (10). Rings appearing on the scales were counted under the microscope. The obtained length (and weight)-at-age is shown in Table 1. Annuli on opercula were not clear, counting was stopped and the opercula discarded.

Table 1. Basic statistics of *Synodus saurus* length (brown row) and weight (green row)-at-age (blue row) based on scale annuli (Min: minimum; Max: maximum).

Basic statistics of the studied fish-sample cohorts based on scale annuli										
Age in years	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Frequency		3	20	24	13	6	2	1	1	0

Mean L(cm		14.2	16.92	19.58	21.56	24.55	27.50	28.5	30	
Min L (cm)		15.7	14.7	16.5	19.1	23.2	27.50	28.5	30	
Max L(cm)		16.1	19.8	21.5	23.3	25.7	27.50	28.5	30	
Mean W(g)		28.5	36.90	54.63	78.62	114.83	160.5	184	239	
Min W(g)		27	24	36	56	104	157	184	239	
Max W(g)		30	63	79	97	131	164	184	239	

Estimating L_∞ and k based on length-at-age obtained from the scales

The Ford – Walford method (Sparre and Venema, 1998), was used. The length-at-age obtained from the scales (Table 1) was tabulated (Table 2) according to t (age), L_t (length at age t), and L_{t+1} (length at age t+1), then the plot of L_{t+1} (on the Y axis) vs. L_t (on the X axis) was performed (Fig. 2). L_∞ and k were calculated from the intercept "a" and the slope "b" of the regression line ($L_\infty = a/(1 – b$, $k = - (1/\Delta t) \ln b$; $\Delta t = 1$).

Table 2. (Down left) Ford – Walford method for estimating L_∞ and k based on length-at-age obtained from the scales (Table 1).

t	L_t	L_{t+1}
	X	Y
1	14.2	16.92
2	16.92	19.58
3	19.58	21.56
4	21.56	24.55
5	24.55	27.50
6	27.50	28.5
7	28.5	30
8	30	

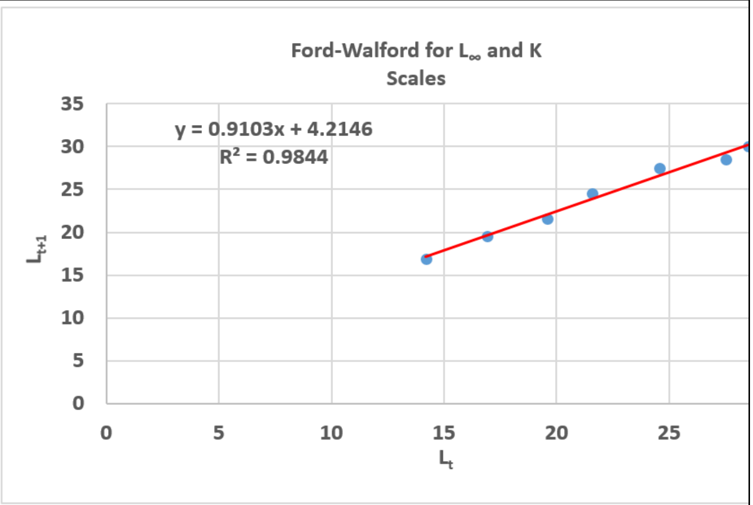

Fig. 2. (Up right) Ford – Walford method for estimating L_∞, k based on the scales (plot of Table 2).

$L_\infty = a/(1 - b) = 4.2146/(1- 0.9103) = 46.99$ cm
$k = - (1/\Delta t) \ln b = - (1/1) \ln 0.9103 = 0.094$ year $^{-1}$

Estimating t_0 based on length-at-age obtained from the scales

The Ford – Walford method (Sparre & Venema,1998), was used. The length-at-age obtained from the scales (Table 1) was tabulated according to t (age), L_t (length at age t) and $- \ln (1 - L_t/L_\infty)$, (Table 3); then the plot of $- \ln (1 - L_t/L_\infty)$ (on the Y axis) vs. t (on the X axis) was performed (Fig. 3). " t_0" was calculated from the intercept "a" and the slope "b" of the regression line ($t_0 = -a/b$).

Table 3. (Down left) The von Bertalanffy method for estimating t_0 based on length at age obtained from the scales; L_∞ = 46.99 cm (Fig. 2).

t	L_t	$- \ln (1 - L_t/L_\infty)$
X		Y
1	14.2	0.3598
2	16.92	0.4464
3	19.58	0.5390
4	21.56	0.6140
5	24.55	0.7391
6	27.50	0.8800
7	28.5	0.9327
8	30	1.0173

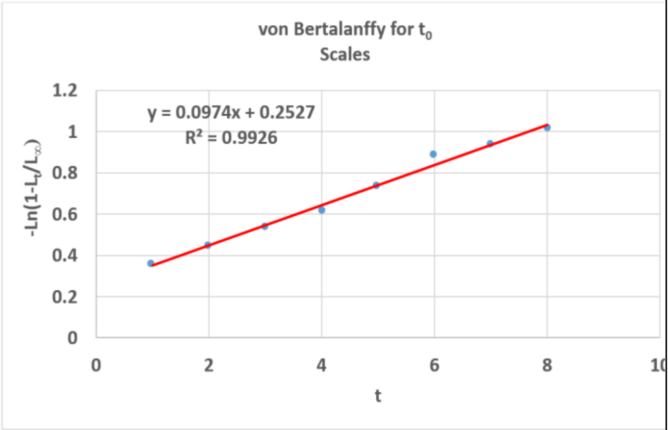

Fig. 3. (Up right) The von Bertalanffy method for estimating t_0 based on the scales (plot of Table 3). t_0 =-a/b = - 0.2527/0.0974 = -2.5944 years

Aging *Synodus saurus* (mean length-at-age) from length frequency distribution

The length-frequency distribution at 0.5 cm intervals (Table 4) of the measured lengths of 600 *Synodus saurus* random sample collected from Benghazi fishing ground was plotted vs total length (Fig. 4). The length-at-age inferred from the curvature (Table 5), as described by Sparre and Venema (1998), was then used to calculate L_∞ and k according to the Ford – Walford method (Table 6, Fig. 5), and t_0 according to the von Bertalanffy method (Table 7, Fig. 6) as detailed before for the length-at age based on annuli of scales (Table 1; Table 2, Fig. 2; Table 3, Fig. 3). Only the length-at-age highlighted green in Table 5 were used further, the ones highlighted red were not used because their frequency was very low.

Table 4. The length (L)-frequency (F) distribution (0.5 cm intervals) of the 600 fish sample.

L cm	F	L cm	F	L cm	F	L cm	F
13.25	0	22.25	16	17.75	37	26.75	1
13.75	2	22.75	18	18.25	44	27.25	2
14.25	2	23.25	18	18.75	56	27.75	1
14.75	2	23.75	11	19.25	39	28.25	0
15.25	8	24.25	8	19.75	37	28.75	0
15.75	23	24.75	1	20.25	44	29.25	1
16.25	38	25.25	5	20.75	29	29.75	0
16.75	38	25.75	5	21.25	37	32.25	1
17.25	57	26.25	2	21.75	18		

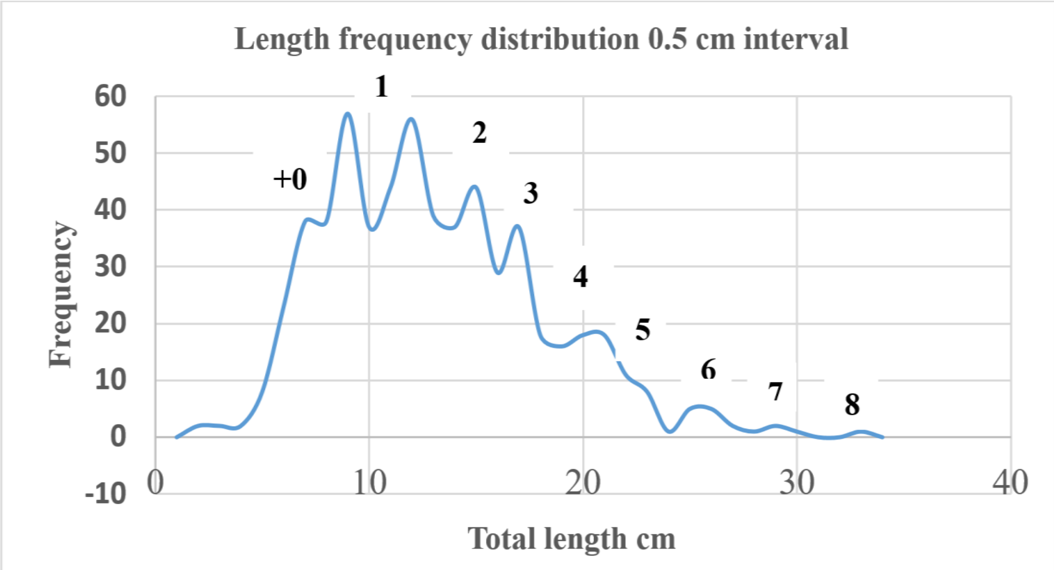

Fig. 4. The plot of the length frequency distribution of *Synodus saurus*, and the obtained length-at-age (Table 6).

Table 5. Basic statistics of *Synodus saurus* length-at-age based on length frequency distribution (LFD) of Fig. 6 (L: fish length in cm).

***Synodus saurus* length-at-age based on LFD**										
Age (years)	**+0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Estimated L	**7.5**	**11**	**15**	**18**	**20**	**22.5**	**25.5**	**29**	**32**	
Frequency	1	58	42	37	19	10	5	2	1	

Table 6. (Down left) The Ford – Walford method for estimating L_∞ and k based on length at age obtained from the LFD (Table 5).

t	**L_t**	**L_{t+1}**
	X	**Y**
1	11	15
2	15	18
3	18	20
4	20	22.5
5	22.5	25.5
6	25.5	

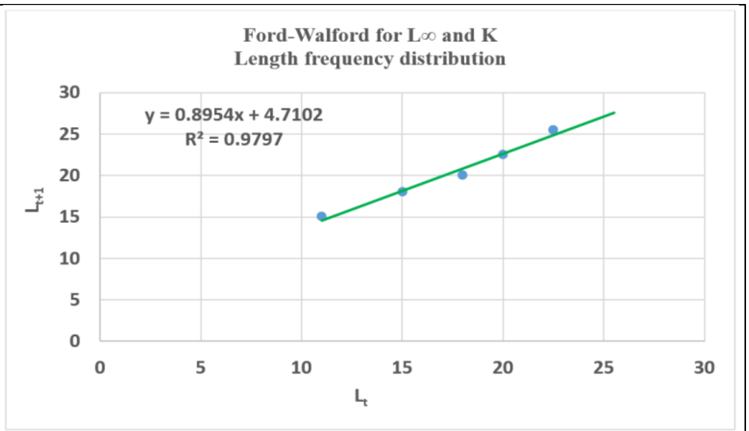

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Fig. 5. (Up right) The Ford – Walford method for estimating L_∞, k based on the LFD (plot of Table 6). L_∞ = a/(1 - b) = 4.7102/(1- 0.8954) = 45.0306 cm. k = - (1/∆t) ln b = - (1/1) ln 0.8954 = 0.1105 year $^{-1}$

Table 7. (Down left) The von Bertalanffy method for estimating t_0 based on length at age obtained from LFD (Table 6).

t	L_t	- ln (1 - L_t/L_∞)
X		Y
1	11	0.2801
2	15	0.4051
3	18	0.5104
4	20	0.5872
5	22.5	0.6925
6	25.5	0.8354

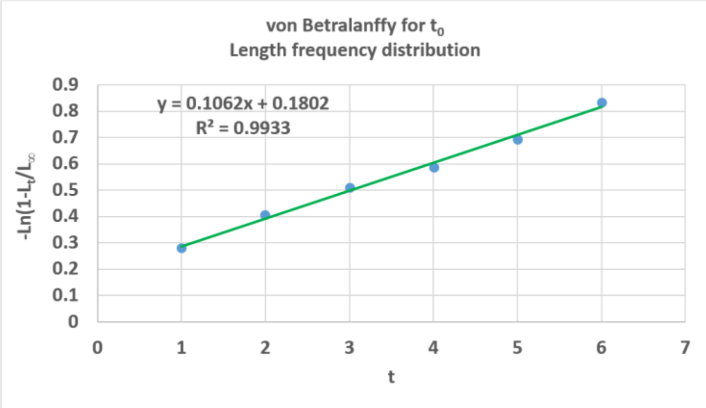

Fig. 6. (Up right) The von Bertalanffy for estimating t_0 based on length at age obtained from LFD (plot of Table 6). t_0 = -a/b = - 0.1802/0.1062 = -1.697 year

The von Bertalanffy calculated with Solver on Excel

The three von Bertalanffy constants, L_∞, k and t_0, were calculated with Solver (So) on Excel (https://www.youtube.com/watch?v=AXlhyvvNRZE) using non-linear least square and maximum likely hood (Hood, 2010; Slipke and Michael, 2013; Diaz, 2021; Cheusheva, 2023). The input data for the Solver were those of Table 1. The obtained constants were: **L_∞ =** 48.2294 cm, **k =** 0.092 year $^{-1}$, **t_0 =** -2.7101 year.

Comparing the models derived from Sc, LFD and So

The Ø, Munro's growth performance index was used to compare the growth modes established for *Synodus saurus* based on Sc, LFD, and So.

$Ø^{/}$ = log 10 K + 2 log $_{10}$ L_∞ as described in Spare and Venema (1998).
$Ø^{/}$ based on Sc = 2.317, LFD = 2.35, So = 2.33

Total mortality (Z) of *Synodus saurus*

Z was calculated by the linearized catch method according to Ricker (1975a, b) and Gulland (1985) as described in Spare and Venema (1998). Z was calculated only from the length-at-age data obtained from LFD because high frequencies were present. First, the length-at-age data obtained from the LFD of Table 5 was tabulated in Table 8, then the plot of Ln Fr (in the X axis) vs. t (in the Y axis) was made (Fig. 7). In Fig. 7, it was clear that the first two data points were not linear with the rest of the points (the other 6 points, which were linear), and so, were dropped and not used further. A new table (Table 9) and plot (Fig. 8) were made using only the 6 linear points. The total mortality was calculated from the slope "b" of the highly linear equation (R^2 = 0.9967) of Fig. 8 as: Ln C (t_1, t_2) = q-z*t. Z = -b = - 0.7286.

Table 8. (Down left) Linearized catch method for estimating total mortality Z based on LFD; (Fr: frequency).

t	L_t	Fr	Ln Fr
X			Y
1	11	58	4.060
2	15	42	3.7377
3	18	37	3.6110
4	20	19	2.9444
5	22.5	10	2.3026
6	25.5	5	1.6094
7	29	2	0.6931
8	32	1	0

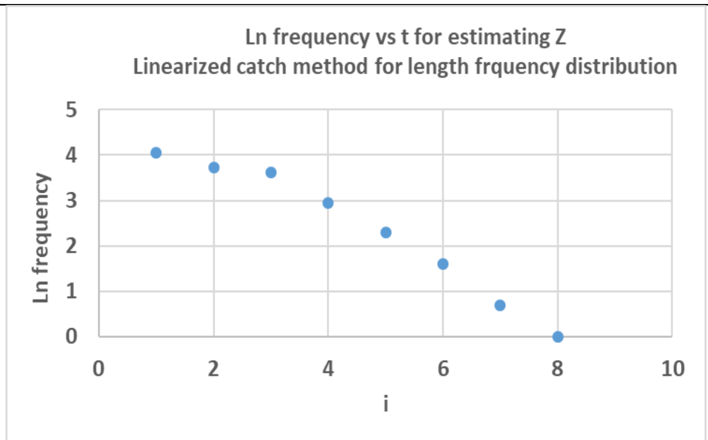

Fig. 7. (Up right) Linearized catch method for estimating total mortality Z based on LFD (plot of Table 8).

Table 9. (Down left) Linearized catch method for estimating total mortality Z based on LFD after removing the non-linear points; (Fr: frequency).

t	L_t	Fr	Ln Fr
X			Y
3	18	37	3.6110
4	20	19	2.9444
5	22.5	10	2.3026
6	25.5	5	1.6094
7	29	2	0.6931
8	32	1	0

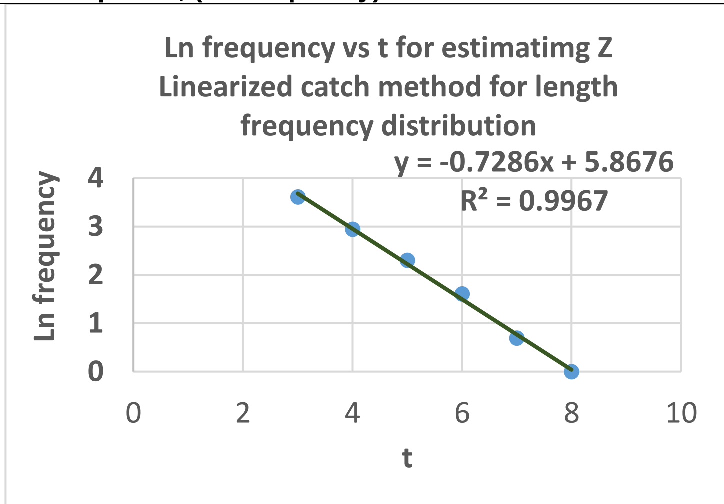

Fig. 8. (Above right) Linearized catch method for estimating total mortality Z based on LFD after removing the non-linear points (plot of Table 9). Z = -b = 0.7286.

Survival rate (S) of *Synodus saurus*

Z: -loge S, or: S: e^{-z}, S based on LFD = $\exp^{-0.7286}$ = 0.4826.

Mortalities of *Synodus saurus*

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Natural mortality "M" was estimated using Pauly's empirical formula:

Ln M = - 0.0152 - 0.279*ln L_∞ + 0.6543*ln k + 0.463*ln T

T, the annual mean temperature of Benghazi costal surface water, was estimated from the satellite CNR MED UHD Sea Temperature Analysis as 25.5 ^{0}C. **L_∞** and **k** were those calculated from Sc and LFD.

Fishing mortality **(F)** was calculated as **F** = Z-M, and the exploitation ratio **E** as F/Z.

Length-at first maturity L_m of *Synodus saurus*

L_m was estimated from Froese and Binohlam (2000) as Log L_m = 0.8776 Log L_∞ -0.38

The von Bertalanffy growth-model constants and the performance index $Ø^/$

The derived von Bertalanffy parameters and the growth performance index Ø/ based on the Sc, LFD and So are given in Table 10a. The values of these parameters are, more or less, comparable, except for t_0, which showed marked differences.

The parameters of biological and ecological importance of *Synodus saurus*

The parameters of biological and ecological importance: Mean length (L), Mean weight (W), Natural mortality (M), total mortality (Z), Survival rate (S), and Length-at first maturity (Lm) calculated from Bertalanffy models based on Sc. LFD and So were, more or less, close (Table 10b), especially those of the Sc and So.

The parameters of fisheries importance of *Synodus saurus*

Total length (L), Total weight (W), Head length/Fish length (H/L), Fishing mortality (F), Length-at first maturity (L_m) Length at optimum yield (L_{opt}), and Exploitation ratio (E) based on Sc, LFD and So are given in Table 10c.

Table 10a- Parameters of Bertalanffy model, Table 10b- biological and ecological parameters, and Table 10c- fisheries parameters of *Synodus saurus* based on the scales (Sc), length frequency distribution (LFD) and Solver (So) methods; (P: parameter).

a Bertalanffy parameters

P	Sc	LFD	So
L_∞ cm	46.99	45.03	48.2
k y^{-1}	0.094	0.110	0.09
t_0 y	-2.59	-1.7	-2.71
$Ø^/$	2.317	2.35	2.33

b Biological parameters

P	Sc	LFD	So
L cm	20.14		
W g	66.93		
M	0.321	0.361	0.314
Z		0.729	
S		0.483	
L_m cm	12.23	11.78	12.51

c Fisheries parameters

P	Sc	LFD	So
L cm	20.14		
W g	66.93		
H/L	0.223		
F		0.368	
L_m cm	12.2	11.78	12.5
E		0.50	
L_{opt} cm	21.98	21.56	22.8

The measured (observed) and calculated (predicted) mean length at age of *Synodus saurus*

The plot of the measured length-at age of *Synodus saurus* (the blue column in Table 11) and the calculated ones based on Sc, LFD, and So (the reddish columns) is shown in Fig. 9. In general, the length-at age calculated by the models based on Sc (orange bullets), LFD (grey bullets), and So (black bullets on an orange disc) were, more-or-less, less than the measured ones (the blue line), however, the differences were not great. The differences are more noticeable at younger and older ages (years 1, 2, 3, 6, 7, and 8). The lengths predicted by LFD based model deviated markedly at younger ages (year 1, 2 and 3).

Table 11. (Down Left) Measured (blue column) and calculated length-at-age based on scales (Sc), length frequency distribution (LFD) and Solver (So) derived from the Bertalanffy models (reddish columns).

Age years	Measu. length (cm)	Calculated lengths (cm)		
		Sc model	LFD model	So model
1	14.2	13.47	11.60	13.37
2	16.92	16.48	15.10	16.25
3	19.58	19.22	18.23	18.89
4	21.56	21.71	21.04	21.29
5	24.55	23.98	23.55	23.48
6	27.5	26.04	25.79	25.48
7	28.5	27.92	27.81	27.30
8	30	29.63	29.61	28.97

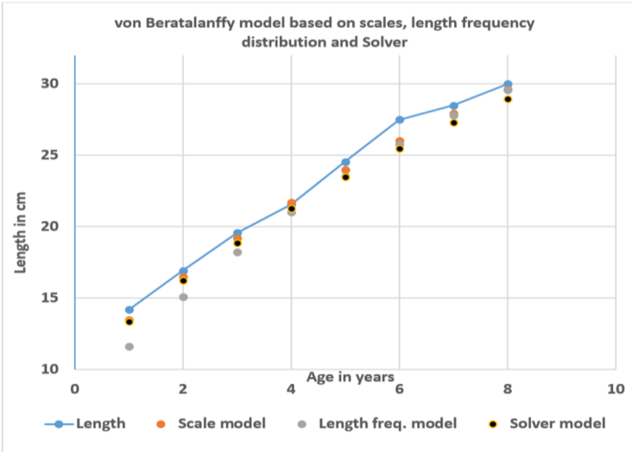

Fig. 9. (Up right) Plot of measured length-at-age and corresponding values predicted by the von Bertalanffy models based on Sc, LFD, and So (Table 11).

Residuals of calculated length-at-age

The residual (R) is the deviation of the calculated lengths-at-age from the measured ones. Therefore, it can be positive (the calculated is more than the measured) or negative (the calculated is less than the measured). Residuals are commonly squared (SR) to maximize extreme deviations and remove the negative sign. Thus, the residuals (R), and their squares (SR), gives an idea to how far the calculated points are close (or not close) to the real (measured) points. Calculates SRs may be summed to give the sum of squares of residuals (SSR), and their means (Mean SSR = SSR/number of data points) tested by ANOVA for significance of differences.

In the present study, R, SR of the lengths-at-age calculated for Sc, LFD and So models are presented in the brown and blue columns of Table 12, while SSRs and their means (Mean SSR) in the green rows at the bottom of the Table. The differences between Mean SSR of Sc, LFD, and So were not statistically significant (Duncan P: 0.06), however, the plot of the residuals vs age shown in Fig. 10 suggests that LFD deviates more from Sc and So, especially at ages 1, 2 and 3 years. A possible cause of this is that the input data (lengths-at-age) used to establish the So model was that of the Sc and not the LFD. Very young fish and very old fish were likely underrepresented in the study samples due to gill-net selectivity in the former and scarcity in the latter.

Table 12. (Down left) Residuals R (light brown columns) of length-at-age calculated by derived Sc, (LFD), and So based models, their squares SR (light blue columns), and their Sum of the Squares SSR (light green cells).

Age years	R Sc cm	SR Sc	R LFD cm	SR LFD	R So cm	S S
1	-0.73	0.53	-2.6	6.73	-0.83	0.
2	-0.44	0.19	-1.82	3.31	-0.67	0.
3	-0.36	0.13	-1.35	1.81	-0.69	0.
4	0.15	0.02	-0.52	0.27	-0.27	0.
5	-0.57	0.33	-1.00	1.01	-1.07	1.
6	-1.46	2.13	-1.71	2.91	-2.02	4.
7	-0.58	0.33	-0.69	0.48	-1.2	1.
8	-0.37	0.13	-0.39	0.15	0.15	0.
SSR		3.80		16.68		8.
Mean SSR		0.47[a]		2.08[a]		1.

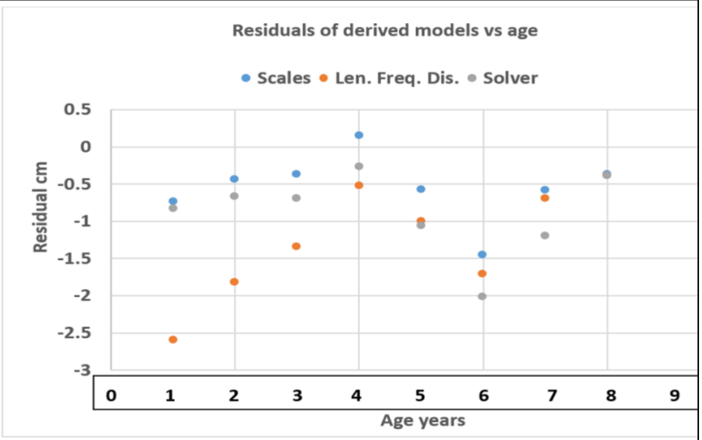

Fig. 10. (Up right) Residuals of derived von Bertalanffy models based on Sc, LFD and So vs age.

Discussion

The *Synodus saurus* of the present study was typical in shape to those described in other studies. The mean size was 20.14±.42 cm total length and 66.93±4.84 gm total weight.

The von Bertalanffy parameters derived in the present study for *Synodus saurus* based on the scales, length frequency distribution and Solver methods were, more or less, comparable, though W_∞ and t_0 were, to some extent, different. However, it must be stressed that on comparing different models, the comparison should not be based on the values of the individual parameter only, but rather, on the function of the whole model as one unit. It is the mutual integrated function of all the parameters that matters. This is because the von Bertalanffy growth model is nonlinear and multi parametric (Spare & Venema, 1998). It is a special generalized logistic function. In the present study, the outcome of the models based on the scales, length frequency distribution and Solver were similar. This can be seen from the similarity of the $Ø^/$ values obtained for the three models, and the closeness of the predicted lengths-at-age obtained by the three models to the measured ones. Ø/, Munro's growth performance index, measures the collective outcome of all the parameters and not their individual values only (Pauly, 1984a, b; Munro & Pauly, 1983; Pauly & Munro, 1984).

The mutual plot of the predicted lengths-at-age to the measured ones almost completely overlaps. However closer examination shows that the scale model, followed by the solver, were relatively more realistic (predicted values closer to the measured ones) than the length frequency model. Analysis of the residuals (the extent of error) of the three models showed that the length frequency distribution model was less sensitive at age 1 year, followed by age

2 and 3, and then age 6 years. The inaccuracy at age 1 year may be explained by high gear selectivity at this young age i.e. the net allows many of the small sized fish to scape. Hence this portion of the population was less represented in the fish sample used to estimate the length-at-age. At higher ages, this model again may be less sensitive because older fish are generally less represented in the population, and hence in the sample. The cause of the inaccuracy of the model at age 2 and 3 years is not clear. The scale and solver models were not affected by such biases. The solver model had an added benefit over the scale and the length frequency models in that it is fairly easy to perform as it requires much less calculations. However, we must keep in mind that it is the function of the model as a whole is what matters more than the values of the individual parameters. Counting scales annuli in tropical and subtropical regions is not always easy (Gallucci *et al*., 1996; Spare & Venema, 1998).

Abd el Rahman and Moghraby (1984) suggested the use of more than one aging method in these regions. The value of t_0 obtained in the present study (-1.697 to -2.71 year-1) were higher than those commonly reported for fish, especially that t_0 is defined as the hypothetical age of the fish when it has zero length, hence is expected to be very small. It is a mathematical and not a biological parameter. Spare and Venema (1998) mentioned that it would approximate reality only when a large unbiased fish sample is used for aging. However, our values were very close to those reported for *Synodus saurus* by some other studies as can be seen from the table below.

Parameter	Scales	LFD	Solver	Other studies*
L_∞ cm	46.99	45.03	48.23	34.3 - 42.1
k year^{-1}	0.094	0.1105	0.092	0.14 - 0.20
t_0 year	-2.594	-1.697	-2.710	-1.52 to -1.89
$Ø^{/}$	2.317	2.350	2.330	2.46 - 2.48

*Ismen *et al*. (2004), Bilecenoglu and Kaya (2002), Derbal *et al*. (2007), Tsikliras and Koutrakis, 2011).

In the present study, the length at first maturity of *Synodus saurus*, L_m, ranged from 11.7 8 to 12.58 cm. In the Syrian Mediterranean Sea, the average L_m of the fish was 18 cm for males and 17.6 cm for females (Ibrahim *et al*., 2020). Other values were 19.7 cm (Ismen *et al*., 2004), 20.2 cm (Bilecenoglu and Kaya, 2005), 21.0 cm (Derbal *et al*., 2007) and 20.8 cm (Tsikliras and Koutrakis, 2011).

In the present study, the total, natural and fishing mortalities were Z = 0.7286 year^{-1} according to the length frequency distribution (LFD), M = 0.3208 year^{-1} (by scales), 0.3609 year^{-1} (by LFD) and 0.314 year^{-1} (by Solver), and F = 0.368 year^{-1}. The exploitation ratio was E = 0.50 (i.e. the resource was being exploited at the maximum sustainable level), and the length at optimum yield (L_{opt}) ranged from 21.56 to 22.89 cm. Preferably, harvesting fish below this range should be avoided. However, this range was above the mean size of the fish sample used in the present study (20.14±.42 cm total length) – a warning sign, but was above the length at first maturity, L_m, (11.78 to 12.51 cm). Theoretically E is maximum when it is half the carrying capacity i.e. K/2 0.5, that is 1/2 r_{max}. (which is the case in the present study). K/2 is the infliction point on the logistic (sigmoid) growth curve, and hence is the point where the growth of the population is at its maximum rate. Exploitation below E = 0.5 means that the resource is not fully exploited; the unexploited portion is left to die naturally and not by fishing. Exploitation above E = 0.5 will initially results in high return, but soon will result in under exploitation in the coming years because the annual population turnover rate cannot compensate the portion removed by fishing. E = 0.5 is the level at which both exploitation and annual turnover rates are equal and maximum (Schaefer, 1954; Ricker, 1975a, b; Hilborn and Walters, 1992; Quinn and Deriso, 1999; Pauly and Froese, 2014; Tsikliras and Rainer, 2019).

Manasirli *et al.* (2011) estimated the total mortality of *Synodus saurus* in the Babadillimanı Bight as Z = 0.4037 year^{-1}. The natural and fishing mortalities were M = 0.2519 and F = 0.1518 year^{-1}, while the exploitation rate was E = 0.37 (i.e. under exploited). Their natural mortality was less than the one estimated in the present study, suggesting that the habitat in the Babadillimanı Bight was better than the habitat of the present study, Benghazi coast, which is essentially a port area.

Conflict of Interest: The authors declare that there are no conflicts of interest.

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