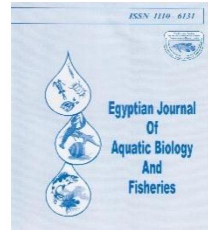
Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(2): 819 – 835 (2021)
www.ejabf.journals.ekb.eg



Age, growth and management of *Amblygaster sirm* (Walbaus, 1792) from the Red Sea, Egypt

Yassein A. A. Osman*; Eman M. Hassanien; Samia M. El-Mahdy; Ashraf S. Mohammad
National Institute of Oceanography and Fisheries, Egypt
*Corresponding author: yasseinahmed66@yahoo.com

ARTICLE INFO

Article History:
Received: March 7, 2021
Accepted: April 20, 2021
Online: April 30, 2021

Keywords:
Age;
Growth;
Mortality;
Amblygaster sirm;
Red Sea .

ABSTRACT

The fishery of the spotted sardinella, *Amblygaster sirm* (Walbaus, 1792) has been the most important catch in the Egyptian waters. The age and growth of the *A. sirm* were updated for the Red Sea, Egyptian waters, in addition to an evaluation of the captures over the last 12 years (2006–2018). To specify the age, more than one reader was determined in the present study. As a result, the recorded life history ranged from 0 to 3 years old. The growth parameters were investigated with various models (von Bertallanfy, Gompertz, Richard and logistic). The growth- length relationship (L_∞) and the growth rate (K) were estimated with 274 mm and 0.35 $year^{-1}$ respectively. The importance of the present study lies in being a biological data provider with respect to sardine species in the Red Sea, and hence the decision to take the action for the management of such species could be elaborated.

INTRODUCTION

The catch of the Red Sea is the second outstanding one after the Mediterranean Sea. It produces about 9499 tons (19.80 %) **(GAFRD, 2020)**, and contains more than one thousand species, most of which lives as associate-reef. Notably, the purse seiner is the most important fishing gear in Egypt that contains many important commercials species (sardine, mackerel, herring, Jacks, trevally and tuna) **(Mehanna & El-Gammal, 2007**; **Samy-Kamal, 2015)**.

The spotted sardinella; *Amblygaster sirm* (Walbaum, 1792), lives at the coastal and lagoon area, known to be pelagic and schooling species **(Letourneur *et al*., 2004)**. Moreover, it is considered marine, reef associate fishes and recorded to inhibit at a depth of 10 to the maximum of 70 m **(Pauly *et al*., 1996).** *A. sirm* is a small species with a maximum recorded length of 27 cm, and common length of 20 cm, while the maximum age was recorded to be 8 years **(Randall, 2005).** It is widely distributed in Indo- West Pacific, including the Red Sea, with an area that extends form Mozambique to Philippine, to Taiwan and Okinawa (Japan) in the North, until New Guinea in the South **(Russell & Houston, 1989)**.

The age and growth were investigated considering different hard parts (scales, otoliths, vertebrae, and spines) with varied methods for otolith, whole, section and burn otolith, based on some readers or some investigaors, and more than one reading for the otolith age **(Boehlert,**

1985; Campana *et al*., 1995; **Campana, 2001)**. Recently, fisheries scientists used the bomb or radiation hydrocarbon to record aging **(Kneebone *et al*., 2008; Andrews *et al.*, 2016; Christiansen *et al*., 2016; Andrews, 2020; Ong *et al*., 2020; Andrews & Scofield, 2021)**.

Condition factors is considered as the most important parameters for fisheries scientist to measure the physical health of stock (population), depending on the plumpness or relative heaviness of the fish in that population. It is very highly important and would indicate good environmental condition (condition of habitat status and availability of prey). Consequently, the fisheries scientist is able to take management recommendation for fish stock based on the ability to monitor fish well- being **(Ogle *et al.*, 2020)**.

There are a lot of studies about age, growth, maturity and exploitation ratio at the Southern Red Sea **(Farrag *et al*., 2018; Mehanna *et al*., 2018; Amin *et al*., 2019; Abdelhak *et al.*, 2020; Mohammad *et al.*, 2020; Osman *et al.*, 2021)**. Based on the limited previous studied information on biology and fisheries of *A. srim* at the Sothern Red Sea, especially at Baranies, this study was conducted to be the first work aimed to provide more information for ageing, growth rate and management of this species.

MATERIALS AND METHODS

Study area and sample collection

A total of 1033 individuals of *Amblygaster sirm* (123 to 240 mm) were sampled from the Baranies landing site during the fishing season of 2019/2020 (Fig. 1). The most catches of sardine mainly come with purse-sein. The main Egyptian catch of sardine was from Baranies **(GAFRD, 2020)** with 1517 and 7288 tons in 2006 and 2018 respectively (Fig. 2).

Fish samples were weighted to the nearest g for the total weight (TW), and to the nearest mm for the total length (TL). The pairs of otolith were removed, cleaned and stored dry for later age determinations.

Length- weight

The length- weight relationship was determined using power function and linear regression **(Le Cren, 1951; Froese, 2006);**

$$W_{i} = \alpha L_{i}^{\beta} 10^{\varepsilon i}$$

Where α and β are parameters and $10^{\varepsilon i}$ is the multiplicative error term for the fit fish. The previous equation is transformed to a linear model by applying common logarithms to both sides and simplifying.

$$\log 10(W_i) = \log 10(\alpha) + \log 10(L i) + \varepsilon^{i}$$

Where ε^i means detecting errors that are additive and will show a constant variability around the line for all lengths.

Age validation

For ageing, totally 483 of sagittal otoliths were cleaned with alcohol 70 % for several seconds before investigation. Otoliths were investigated with stereoscopic (Carl Zeiss

Discovery v20 connects to AxioCam ERc5s camera with software), and the reflected light and a black background with the magnification of microscope (26x) were used. The growth rings on the otoliths were counted to determine the maximum life span of *A. sirm*.

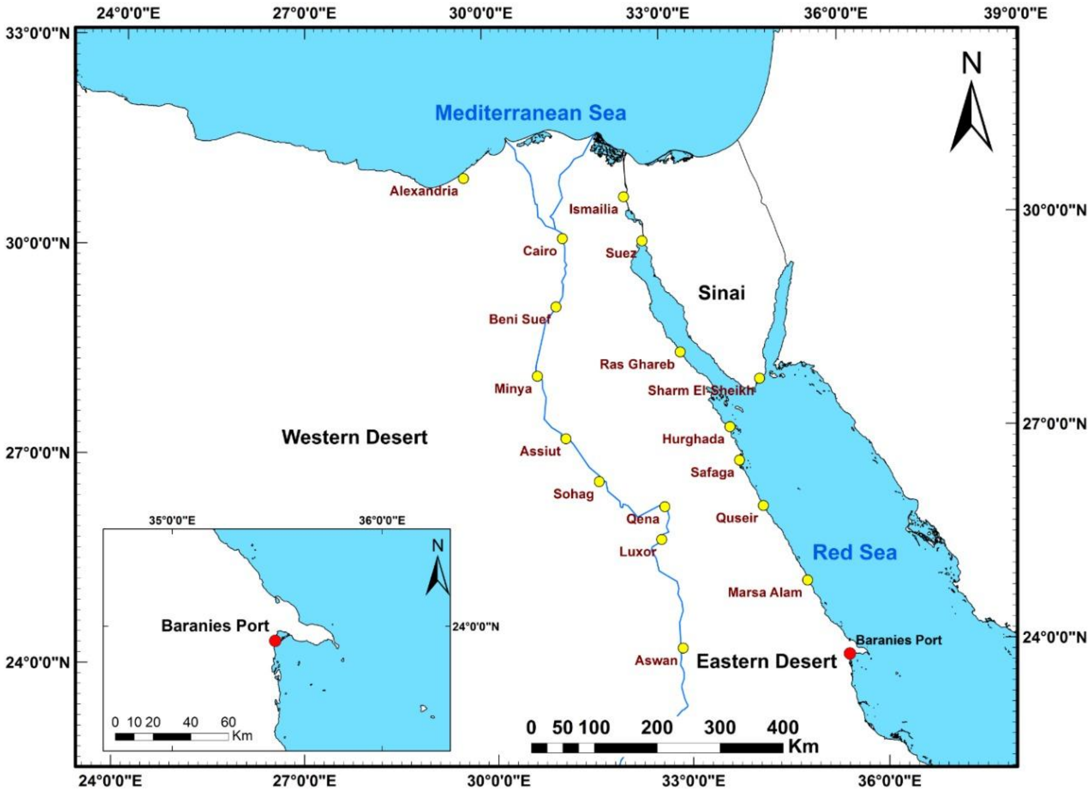


Fig. 1. A map showing Baranies port in Foul bay (study area), Red Sea, Egypt.

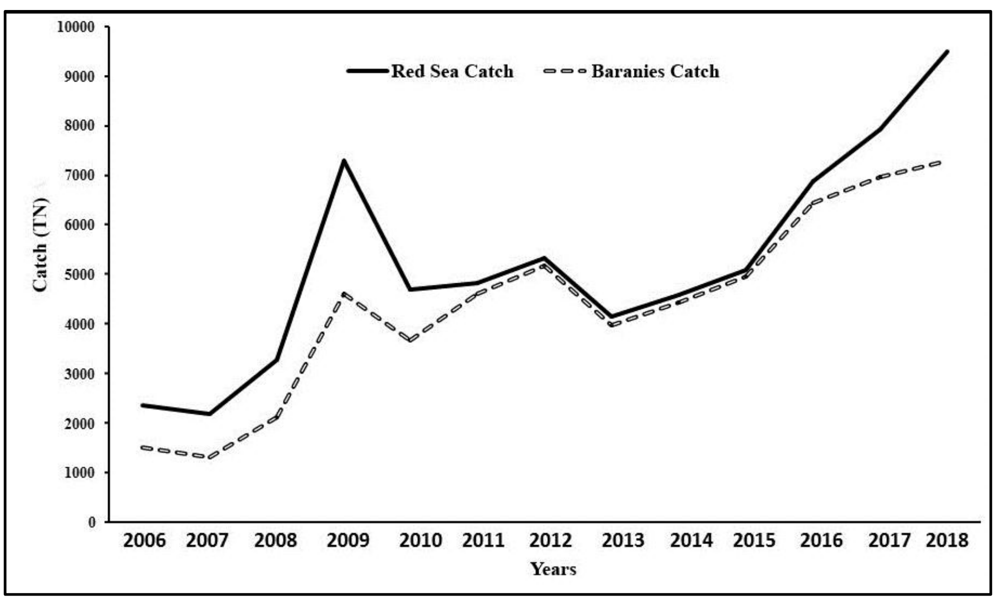


Fig. 2. Trends of spotted sardinella in total landings in the Egyptian Red Sea coast and

its landings in Baranies port, in the last decade (2006-2018) (GAFRD, 2020).

Age bias and precision

The two reader were used to decrease the bias and precision, for age bias plots **(Campana *et al.*, 1995** and **Campana, 2001)**, Variation Coefficient (CV), percent error of absolute (APE) and agreement of percent (PA; ±1 y) were suggested to estimate the age precision **(Beamish & Fournier, 1981; Chang, 1982** and **Dwyer *et al*., 2003)**. The Precision metrics were described as the following equation:

$$\mathbf{CVj}\ (\%) = \mathbf{100} \times \frac{\sqrt{\sum_{i=1}^{R} \frac{(\boldsymbol{X}\mathbf{ij} + \boldsymbol{Xj})^2}{\boldsymbol{R}-\mathbf{1}}}}{\boldsymbol{Xj}}$$

Where R is the number of times each fish is aged, Xij is the i(th) ageing of the j(th) fish, X_j is the mean age calculated for the j(th) fish, and n_{diff} is the age variation for the two readers.

Age and growth function

For age and growth, four models were used to fit length at age data including: von Bertalanffy, Gompertz, Richards, and logistic growth functions. For the first model, the von Bertalanffy growth function (VBGF, **von Bertalanfy, 1938**) contains different parametrization or function; typical von Bertalanffy function, the Francis function **(Francis, 1988)**, and the schnute function **(Schnute, 1981)**. The second model gompertz model or function **(Gompertz, 1825)** includes varied function parametrization: first Ricker function **(Ricker, 1975)**, third Ricker parametrization **(Ricker, 1979)**, and third Quinn and Deriso **(Quinn & Deriso, 1999)**. Thirst models, Richards models or function **(Richards, 1959)**, contains different functions, first Richards, second Richards third Richards and fourth Richard parametrization **(Richards, 1959)**. Fourth model, logistic function, first Campan- Jones and second Campana – Jones parametrization **(Campana & Jones, 1992),** Karach parameterization **(Karkach, 2006)**. The species functions are nonlinear, and thus require nonlinear model letting methods to get the function to data **(Ogle *et al.*, 2020)**.

Condition factors

The condition factors were estimated with the relative weight; a factor that considers the the most common value to evaluate the condition **(Blackwell *et al*., 2000; Ogle *et al.*, 2020).** The relative weight was used for an individual **(Wege & Anderson, 1978)** for fish specimens as follows:

$$\boldsymbol{Wri} = \frac{\boldsymbol{Wi}}{\boldsymbol{Wsi}} * \mathbf{100}$$

Where Wsi is the standard weight for specimens of the same investigated length. The standard weight is either computed with the log-transformed linear model,

$$\boldsymbol{Wsi} = \mathbf{10\alpha+\beta log10(Li)}$$

or the log-transformed. quadratic model

$$Wsi = 10\alpha+\beta 1\log 10(Li)+\beta 2\log 10(Li))^2$$

For the relative factor, two methods were used: the analysis of variance one way (ANOVA) to estimate the means. The hypothesis null of ANOVA test indicates the sample that has the same mean, while the alternative hypothesis is that the mean for at least one group varied from the mean of other group/s. The other method is Tukey's Honestly Significant Difference (HSD) method **(Aho, 2014)**. The Kruskal- Wallis test is equivalent to the one- way (ANOVA). If the distributions are similarly shaped with equal variances among groups, then all groups will have equal medians **(Hollander *et al*., 2013; Aho, 2014)**. Furthermore, **Dunn (1964)** described a procedure for the Kruskal-Wallis test, which is implemented in dunn test by FSA.19.

Mortality

Length compositions were converted to age frequencies using age-length keys to estimate the total mortality (Z) using catch curves **(Ricker, 1975)**. The ageing data for *A. sirm* were suggested to estimate Z to ensure the regression based only on fully selected individuals **(Ricker, 1975)**. **Kenchington (2014)** suggested the most common approaches to get natural mortality. The approaches described in the study of **Then *et al*. (2015)** are taken from those of **Pauly (1980)** and **Hoenig (1983). Pauly (1980)** stated the equation as follows:

$$M = 10^{-0.0066-0.279\log 10(L\infty)+0.6543\log 10(K)+0.4634\log 10(T)}$$

Hoenig (1983) for all stocks combined,

$$M = e^{1.44-0:982\log e(t_{max})}$$

Or, for only the fish stocks,

$$M = e^{1.46-1.01\log e(t_{max})}$$

Where t_{max} is the maximum age of the fish stock.

Then *et al*. (2015) recommended the following equation to be used when possible,

$$M = 4.899t_{max}^{-0.916}$$

but that

$$M = 4.118K^{0.73}L_{\infty}^{-0.33}$$

could be used if t_{max} was not available. The above equations are called "PaulyL", "HoenigO", "HoenigOF", "tmax", and "PaulyNoT" respectively. The exploitation rate (E) was calculated as the proportion of fishing mortality relative to the total mortality (E=F/Z). The mortality was investigated by using the FSA packages in R **(Ogle *et al*., 2020).**

RESULTS

Length- weight relationship

The length- weight relationship is labeled with intercept (Fig. 3), slop parameters is labeled with the explanatory variables from lm, thus the slope is 3.16 (95% CI: 3.10, 3.21; Standard error= 0.0278; Pvalue, <2e-16) and the intercept at -5.38 (95% CI: -5.51, -5.26; standard error= 0.0638; P value, <2e-16), the growth type is positive allometric. The p value (under Pr(>|t|)) for tow- tailed test equals zero. The p value is very small in the logTL, so the slope is significantly varied than zero, which indicates that the relationship between logW and log TL is significant.

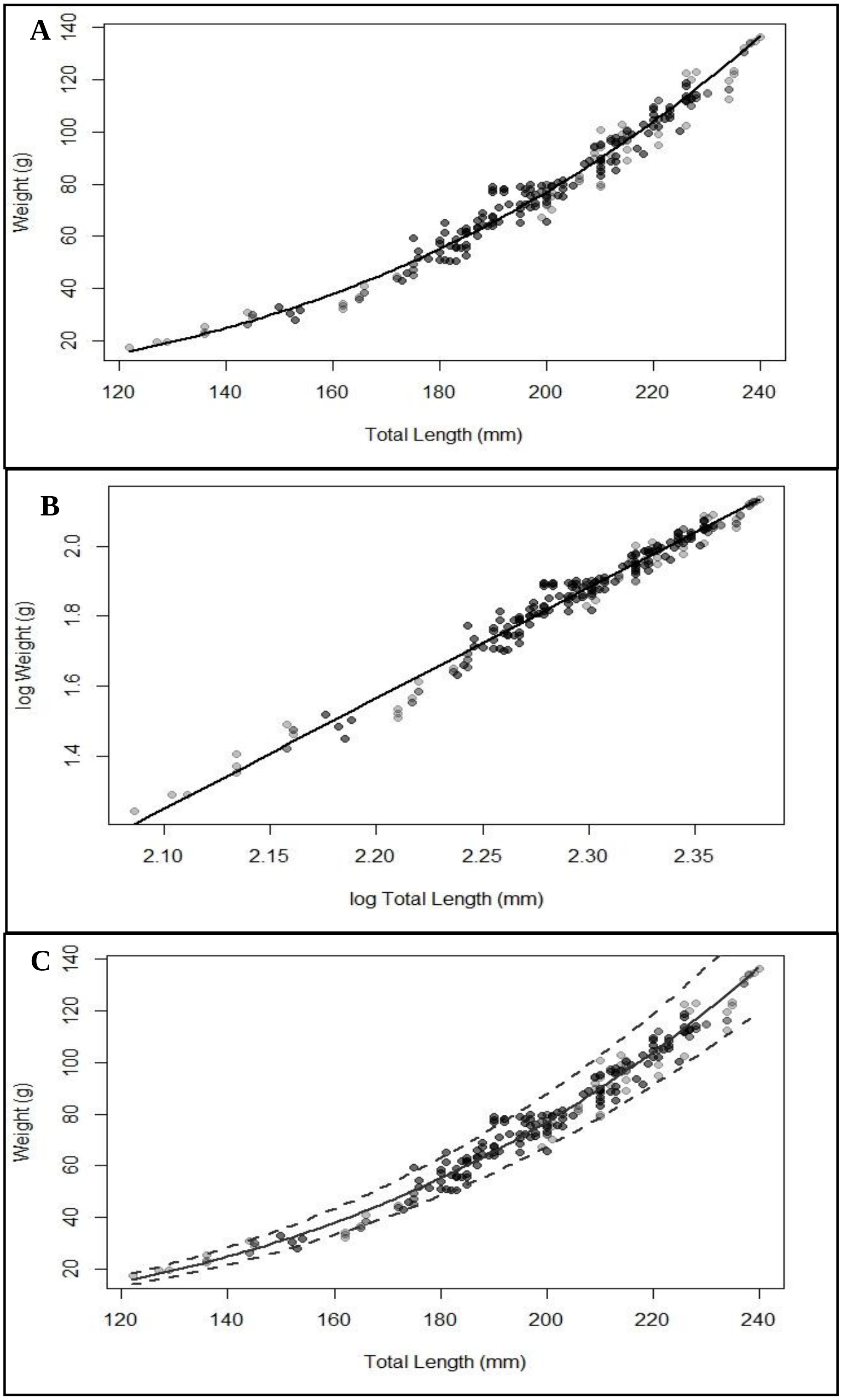


Fig. 3. The weight-length data with the back transformed best fit line superimposed for *A. sirm* (A), *A. sirm* log10-log10 transformed weight-length data with the best fit line superimposed (B) and *A. sirm* weight-length data with the best fit model (solid line) and 95% prediction bands (dashed lines) superimposed (C).

Age validation

For ageing, the 484 samples were selected to determine age and growth zone. After investigation they were recorded as 0 to 3 years in whole otolith (Fig. 4). The age bias plot (Fig. 5) reresents the comparison between two readers for *A. sirm* that were estimated (n= 483; percent agree= 93; ASD= 0.048; ACV= 3.92; AAD= 0.034; APE= 2.77).

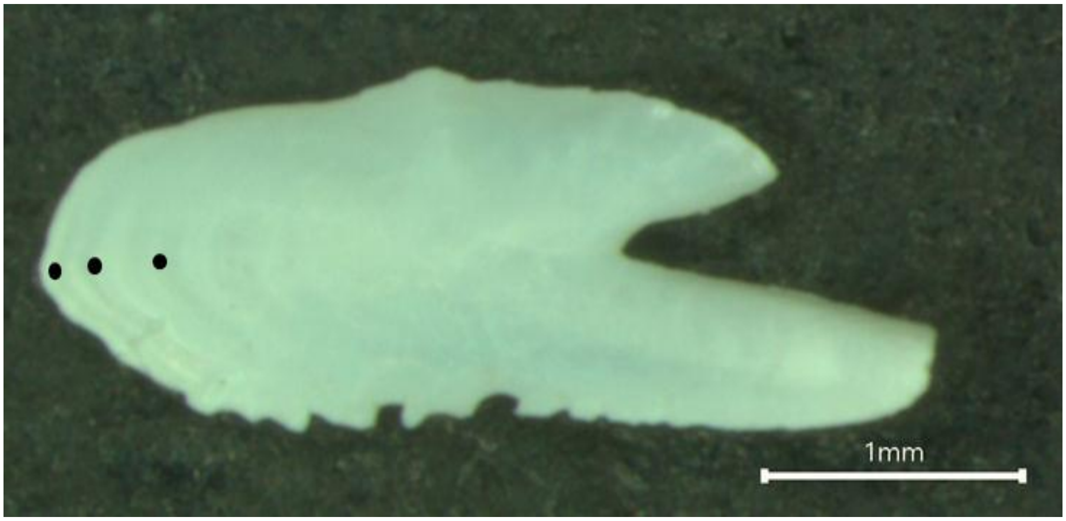


Fig. 4. Otolith of *A. sirm*, age = 3 and length 235, with scale bar.

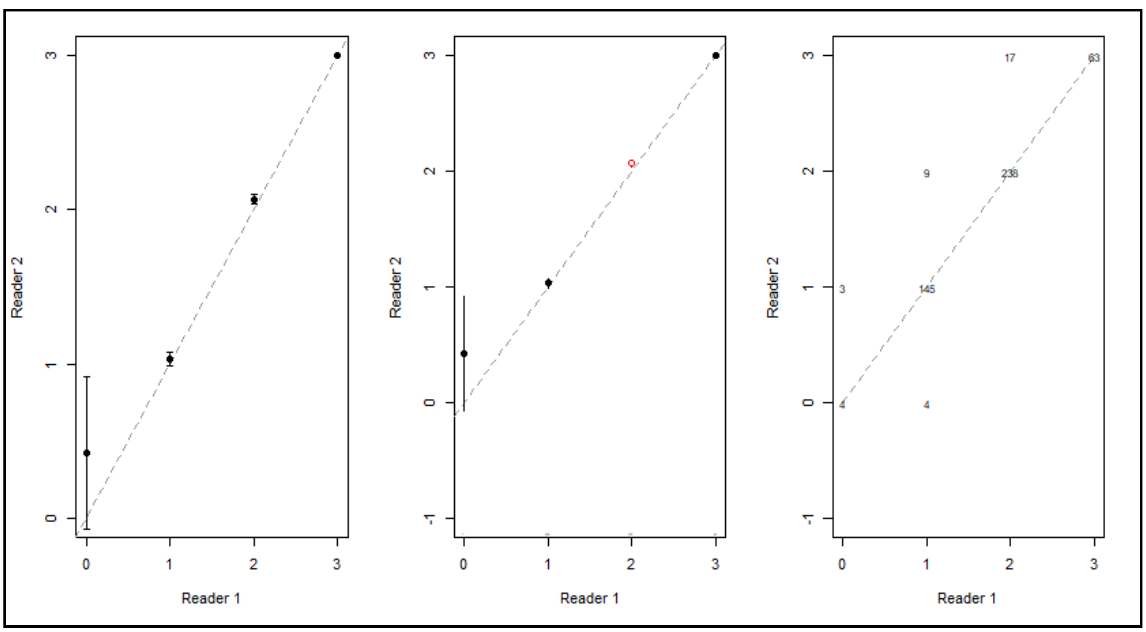


Fig. 5. The age bias between reader 1 and reader 2 for *A. sirm*.

Age and growth

The age length key is determined in Table (1). The ages of *A. sirm* were determined as 0 to 3 years old, where the age III has the most occurrence in the present study during the investigated period. The growth von Bertalanffy parameters using age estimates from the whole otoliths were variables (Table 2). The von Bertalanaffy growth parameters L_∞, K and t_0 were determined as 275.5mm, 0.35year^{-1} and -1.95 year^{-1} respectively. There are significant values for the von Bertlanafy parameters; L∞, k and t_0. The Gompertz function the growth parameters L_∞ was determined at 270.52mm for the first Ricker and the third Quinn and Deriso receptively, while L_0 at 19.02, t_0 -1.18year for the third Ricker, the gi had the same outputs as 0.27 for the three functions (first Ricker, third Ricker and third Quinn and Deriso). There are significant values for the Gompertz parameters; L_∞, gi, ti and t_0. For the third model, Richard function, L_∞ was at 270.52, 259.03 and 259.03 mm for the first Richard, third Richard and fourth Richards parametrization, respectively. The K value has the same estimated value, recording 0.40 year^{-1} for the third Richard and fourth Richards parametrization, No significant values was recorded for the growth parameters of Richard function. On the other hand, the logistic model recorded significant values for all growth parameters. The values of L_∞ were determined at 205.14 for the first Campana-Junes, second Campana-Junes and Karkach. Additionally, the gninf had the same value as 0.57 for the parametrizations.

Table 1. Age- length key for *A. sirm* in the Foul bay based on otolith reading.

Length (mm)	0	I	II	III
120	3			
130	2	1		
140	2	4		
150		12		
160		9		
170		27		
180		90		
190		15	75	
200			63	
210			90	
220			27	48
230				14
240				1
Total No.	**7**	**158**	**255**	**63**
Mean± SD	**132.29±10.16**	**178.24±11.73**	**205.99±8.84**	**227.86±4.33**

Table 2. Parameters of each growth model for females and males of *A. sirm* by location.

von Bertalanffy			**Typical**			
		Estimate	**Std. Error**	**t value**	**Pr(>|t|)**	
	Linf	275.5	12.51	22.02	< 2e-16	***
	K	0.35	0.056	6.28	7.79e-10	***
	t0	-1.95	0.24	-8.06	6.21e-15	***
			Francis			
	L1	136.36	2.97	45.95	<2e-16	***
	L2	193.31	0.583	331.60	<2e-16	***
	L3	226.94	1.13	200.28	<2e-16	***
			Schnute			
	L1	136.37	2.97	45.95	<2e-16	***
	L3	206.54	0.54	383.37	<2e-16	***
	K	0.35	0.056	6.28	7.8e-10	***
Gompertz			**First Ricker**			
	Linf	270.52	26.89	10.10	<2e-16	***
	gi	0.30	0.02	14.92	<2e-16	***
	ti	3.29	0.31	10.52	<2e-16	***
			Third Ricker			
	L0	18.2	0.48	37.60	<2e-16	***
	a	2.70	0.078	34.86	<2e-16	***
	gi	0.30	0.020	14.92	<2e-16	***
			Third Quinn and Deriso			
	Linf	270.52	26.79	10.10	< 2e-16	***
	gi	0.30	0.020	14.92	< 2e-16	***
	t0	-0.68	0.18	-3.82	0.000153	***
Richards			**First Richards**			
	Linf	270.52	26.79	10.10	<2e-16	***
	gi	0.30	0.020	14.92	<2e-16	***
	ti	3.30	0.31	10.52	<2e-16	***
			Second Richards			
	L0	18.22	0.48	37.60	<2e-16	***
	a	2.70	0.077	34.86	<2e-16	***
	gi	0.30	0.020	14.92	<2e-16	***
			Third Richards			
	Linf	259.03	177.95	1.46	0.15	
	k	0.32	0.30	1.10	0.29	
	ti	3.21	1.21	2.58	0.010	*
	b	0.04	0.64	0.061	0.95	
			Fourth Richards			
	Linf	259.03	177.95	1.46	0.15	
	k	0.32	0.30	1.07	0.29	
	ti	3.21	1.25	2.58	0.010	*
	b	1.04	0.64	1.62	0.11	
Logistic			**First Campana-Jones**			
	Linf	152.42	5.96	25.59	<2e-16	***
	gninf	0.77	0.022	34.45	<2e-16	***
	ti	2.50	0.10	24.07	<2e-16	***
			Second Campana-Jones			

Linf	152.42	5.96	25.59	<2e-16	***
gninf	0.77	0.22	34.45	<2e-16	***
a	6.80	0.20	33.83	<2e-16	***
		Karkach			
Linf	152.42	5.96	25.59	<2e-16	***
L0	19.55	0.39	50.16	<2e-16	***
gninf	0.77	0.22	34.45	<2e-16	***

VBGF = von Bertalanffy growth function using set Lo; L∞ = asymptotic total length in cm; k and g = growth coefficients; t_0 = theoretical age at 0 length; L_0 = total length at birth in mm.

Condition factors

The condition factors were determined with the relative weight, where the ANOVA was estimated at the p-value (p= 0.00015) from this output. The mean was estimated from at least one group that varied from the mean of one other group or more than one. This indicates that the one- way ANOVA is not accepted, because it does not give or tell which mean is different. From the Tuckeys test, the difference in the means for each pair of group is significantly from zero. The p-values is significantly for all pairs (Table 3).

Table 3. Relative weight of condition factor of *A. sirm* during the study period from Baranies landing site.

	DF	chi-squared/	Comparison	Z/ estimated	P.unadj/ St. Error	P.adj	F value	Pr(>F)
ANOVA	2	490.7	---	---	---	---	9.1066	0.00015***
Tuckey's	---	---	memorable - preferred	-8.8087	2.2888		-3.849	0.0004***
	---	---	memorable - trophy	-5.9519	2.1447		-2.775	0.0143*
	---	---	preferred - trophy	2.8568	0.9262		3.084	0.0056 **
Levene Test(aov1)	2	---	---	---	---	---	0.8326	0.436
Kruskal-Wallis	2	19.709	---	--	---	---	---	0.0001***
DunnTest	---	---	memorable - preferred	-3.92053	0.00009	0.000265	---	---
	---	---	memorable - trophy	-3.33287	0.00086	0.001719	---	---
	---	--	preferred - trophy	2.744586	0.00606	0.006059	---	---

The mean value of relative weight with Gabelhouse length category for spotted sardines captured during 2020 is illustrated in Fig. (6). The statistically variation means is found with different letters. The residual plot and histogram form, fitting a one-way ANOVA to relative weight by Gabelhouse length category for spotted sardine captured in 2020, were illustrated in Fig. (7). For Levene test, the p-value was large (p= 0.436) which led to the propable equality of the variances, and caused the homoscedasticity assumption to likely meet.

The Kruskal- Wallis test, the p-value was very small (p= 0.0001), an estimate that led to the case in which the medina for one group differed from one or more than one group. Considering the dunn test, those results suggest that the median relative weight for quality-length of *A. srim* was significantly greater than that of the preferred-length of *A. sirm* and may be greater than that of the memorable-length of *A. sirm*. Nevertheless, the median relative weight did not appear to differ in any other pairs of length categories.

Mortality

The mortality estimate of *A. sirm* was 3 years. Remarkably, the mortality estimates were obtained from the Chapman-Robson method catch curves. The total annual survival and mortality rate of *A. sirm* was 43.2%, the standard error was 1.73 (Z=0.84 year^{-1} and the standard error was 0.58. Correlates provided an M value of 0.62 year^{-1}. The estimated average of natural mortality was M=0.62 year^{-1}. Whereas, the estimated fishing mortality(F) for both sexes combined was 0.12 year^{-1} (E=14% year^{-1}). In this essence, the value was below the F/M < 1 threshold.

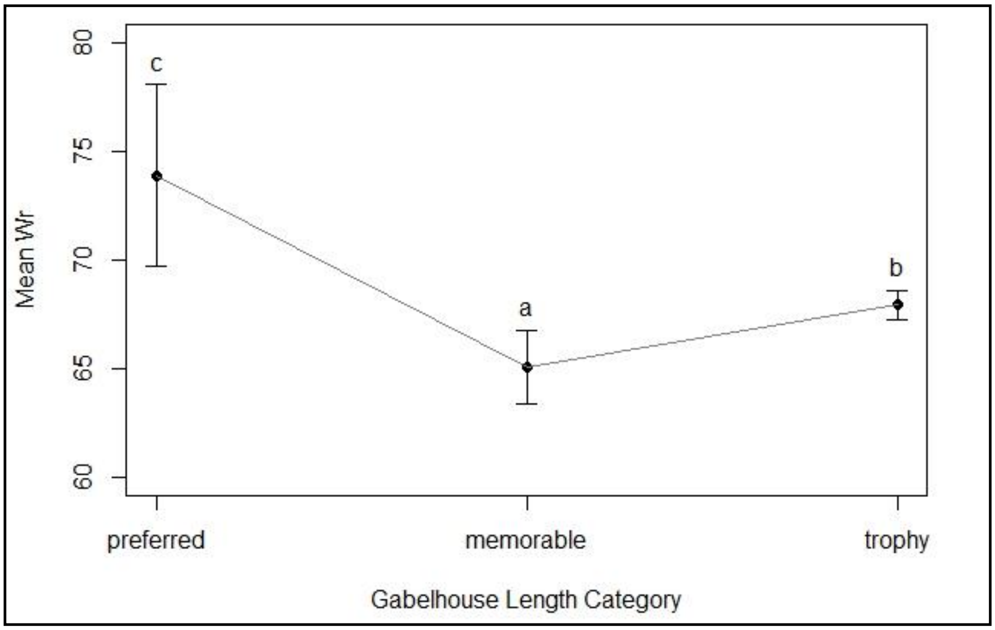


Fig. 6. Mean relative weight by Gabelhouse length category of *A. sirm* captured in 2020.

Vertical lines indicate 95% confidence intervals for the mean. Means with a common letter are not statistically different.

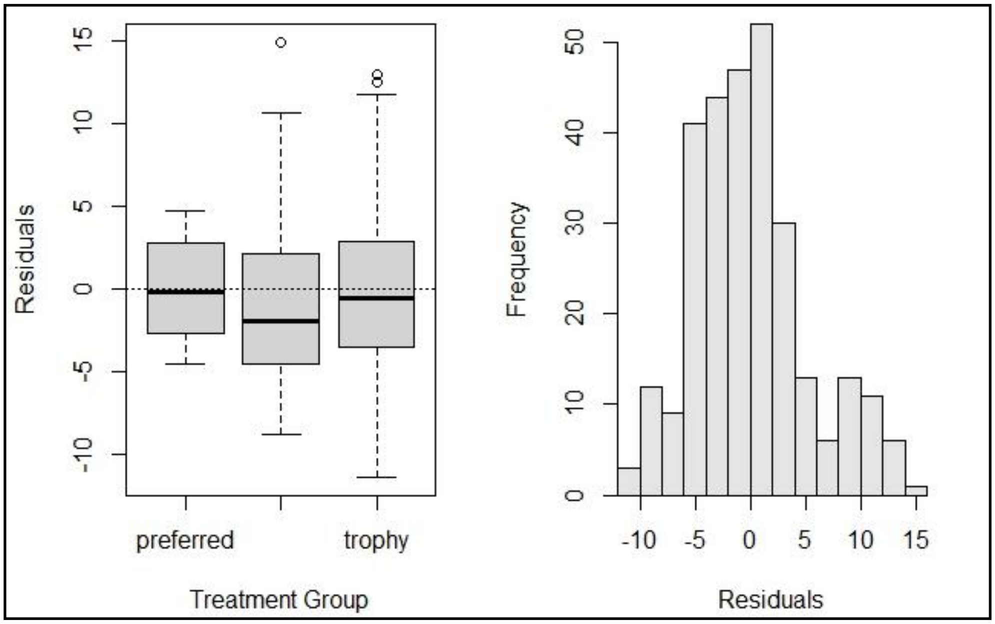


Fig. 7. Residual plot (Left) and histogram of residuals (Right) from fitting a one-way ANOVA to relative weight by Gabelhouse length category of *A. sirm* captured in 2020.

DISCUSSION

The length-weight relationship is very important to get the fish stock assessment; it is used to get weight from a known length **(Sinovčić *et al.*, 2004; Gabr & Mal, 2017).** The exponent 'b' of the weight- length relationship may be useful for inter- or- intra species comparison of fish of varied habitats and locations **(Campana, 2001; Froese, 2006; Katsanevakis & Maravelias, 2008; Ogle *et al*., 2020**; **Osman *et al.*, 2020)**. The length- weight is a very important parameter to get the growth type. The current results revealed that, the growth type was positive allometric (b= 3.15), these outputs might have the same growth type **(Athukoorala *et al*., 2015)**, where b= 3.438 and 3.386 for males and females respectively.

Age validation

The age bias and precision which data requires to get fish status for any population or stock. Thus, in the present study, the age bias was determined to range from 0 to 3 years old, and the level of agreement and indices of precision was estimated (Percent Agree= 93; ASD= 0.048; ACV= 3.92) to get the highly precision, because reader reread otolith more than once to get the close reading for the whole otolith of the *A. sirm*. The problem to estimate age in older fish lies in the fact that there is an error in numerous documents concerning deep-sea species in other regions **(Le Cren, 1951; Andrews *et al.*, 2011)**. Though the APE values were low in the present study, yet it is worthy to mention that the previous studies used the length frequencies for the same species **(Pradeep *et al*., 2014)**.However, in the current study the indicter used the precisions of this species to estimate age by more that one reader (repeated age reading) to avoid the bias **(Campana, 2001)**. The high precision between readers suggests that the whole otolith is the preferred method to age this species.

The age and growth

The age and growth were determined for the first time for this species in this region with a whole otolith. The study of age and growth is highly required to get a status of stock population, using the uppermentioned parameters, maximum length, growth coefficients and t_0. The von Bertalanffy, Gompertz, Richard, and Logistic models were used in this study to find the growth parameters. The growth parameters were determined as 275.5, 0.35 and -1.95 for L_∞, K and t_0. Hence, these resuls disagree with those reported by **Dayaratne and Sivakumaran (1994)**, who estimated the L_∞ by 24.6 cm and K value by 1.3 in Sri Lankan waters. In addition, the present findings disagree with those estimated in Andaman waters **(Pradeep *et al*., 2014)**, stating that the $L\infty$ was 274.1mm, K=0.77/year and t_0 = - 0.0837 with ELEFAN I of FiSAT, so von Bertalanffy growth equation $L\infty = 274.1[1\text{-}e^{-.77(t-\ t0)}]$, Shepard's method with the same $L\infty$ value gave K= 0.22/year. Furthermore, for Powell and Wetherall method, L_∞ = 255.6mm and Z/K =2.62. The difference in the results between the present study and the previous may be due to some reason like: water temperature, localities, seasons, sampled number, methods sex and maturity **(Tesch, 1971; Pitcher & Hart, 1982)**.

Mortality rate and exploitation ratio

The total mortality coefficient was estimated by 0.84 $year^{-1}$, natural mortality by 0.72 $year^{-1}$, and fishing mortality by 0.12 $year^{-1}$. The exploitation ratio was found to be 0.14 $year^{-1}$. Consequently,the current stock must be decreased by 14% to keep the production. The current study may be different with that estimated in the previous studies of **Pradeep *et al*. (2014)** , where the mortality values were 2.14, 0.80, 1.34 and 0.63 $year^{-1}$ for the total natural fishing mortalities and exploitation ratio respectively.

Condition factors

There are important factors to measure the fish physical health called condition factors, which are used by several models, among which the metric of relative weight is considered the most common measuring model **(Bolger & Connolly, 1989; Blackwell *et al*., 2000; Pope, 2007; Ogle & Winfield, 2009; Cooney & Kwak, 2010; Neumann *et al*., 2012)**.

CONCLUSION

The present study focused on the age, growth, mortality and condition factor to provide more biological information for the species of *Amblygaster sirm* (Walbaus, 1792) from the Red Sea, and the region of Baranies landing site. Nevertheless, this region still needs more studies to investigate other species (landed by trawl and purse seine fishery).

REFERENCES

Abdelhak, E.; Madkour, F.; El Ganainy, A.; Abu El-Regal, M. and **Ahmed, M. (2020).** Reproductive biology of *Siganus rivulatus* (Forsskal, 1775) in the Red Sea, Suez Canal and the Mediterranean Sea, Egypt. Egypt. J. Aquat. Biol. Fish., **24**: 117–134.

Aho, K. (2014). Foundational and Applied Statistics for Biologists Using R. Chapman & Hall/CRC, Boca Raton, FL. pp.1040–1041 .

Amin, A.; El-Ganainy, A.A. and **Sabrah, M. (2019).** Fishery status of the longnose parrotfish, *Hipposcarus harid* (Forsskal, 1775) in the southern Red Sea, Shalateen, Egypt. Egypt. J. Aquat. Biol. Fish., **23**: 451–459.

Andrews, A.H. (2020). Giant trevally (*Caranx ignobilis*) of Hawaiian Islands can live 25 years. Mar. Freshw. Res., **71**: 1367–1372.

Andrews, A.H.; DeMartini, E.E.; Eble, J.A.; Taylor, B.M.; Lou, D.C. and **Humphreys, R.L. (2016).** Age and growth of bluespine unicornfish (*Naso unicornis*): a half-century life-span for a keystone browser, with a novel approach to bomb radiocarbon dating in the Hawaiian Islands. Can. J. Fish. Aquat. Sci., **73**: 1575–1586.

Andrews, A.H.; Kalish, J.M.; Newman, S.J. and **Johnston, J.M. (2011).** Bomb radiocarbon dating of three important reef-fish species using Indo-Pacific $Δ$14C chronologies. Mar. Freshw. Res., **62**: 1259–1269.

Andrews, A.H. and **Scofield, T.R. (2021).** Early overcounting in otoliths: a case study of age and growth for gindai (*Pristipomoides zonatus*) using bomb 14C dating. Fish. Aquat. Sci., **24**: 53-62.

Athukoorala, A.; Bandaranayaka, K.H.K. and **Haputhantri, S.S.K. (2015).** A study on some aspects of reproductive biology and population characteristics of *Amblygaster sirm* in the west coast of Sri Lanka. Int. J. fish. aquat. Stud., **2**: 41–45.

Beamish, R.J. and **Fournier, D.A., (1981).** A method for comparing the precision of a set of age determinations. Can. J. Fish. Aquat. Sci., **38**: 982–983.

Blackwell, B.G., Brown, M.L. and **Willis, D.W. (2000).** Relative weight (Wr) status and current use in fisheries assessment and management. Rev. Fish. Sci., **8**: 1–44.

Boehlert, G.W. (1985). Using objective criteria and multiple regression models for age determination in fishes. Fish. Bull., **83**: 103–117.

Bolger, T. and **Connolly, P.L. (1989).** The selection of suitable indices for the measurement and analysis of fish condition. J. Fish Biol., **34**: 171–182.

Campana, S.E. (2001). Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. J. Fish Biol., **59**: 197–242.

Campana, S.E.; Annand, M.C. and **McMillan, J.I. (1995).** Graphical and statistical methods for determining the consistency of age determinations. Trans. Am. Fish. Soc., **124**: 131–138.

Campana, S.E. and **Jones, C.M. (1992).** Analysis of otolith microstructure data. Otolith Microstruct. Exam. Anal. Can Spec Publ Fish Aquat Sci., **117**: 73–100.

Chang, W.Y.B. (1982). A statistical method for evaluating the reproducibility of age determination. Can. J. Fish. Aquat. Sci., **39**: 1208–1210.

Christiansen, H.M.; Campana, S.E.; Fisk, A.T.; Cliff, G.; Wintner, S.P.; Dudley, S.F.J.; Kerr, L.A. and **Hussey, N.E. (2016).** Using bomb radiocarbon to estimate age and growth of the white shark, *Carcharodon carcharias*, from the southwestern Indian Ocean. Mar. Biol., **163**: 1–13.

Cooney, P.B. and **Kwak, T.J. (2010).** Development of standard weight equations for Caribbean and Gulf of Mexico amphidromous fishes. North Am. J. Fish. Manag., **30**: 1203–1209.

Dayaratne, P. and **Sivakumaran, K.P. (1994).** Biosocioeconomics Of Fishing For Small Pelagics Along The Southwest Coast Of Sri Lanka. Bay of Bengal Programme, Colombo, Sri Lanka. BOBP/WP/96.

Dunn, O.J. (1964). Multiple comparisons using rank sums. Technometrics 6, 241–252.

Dwyer, K.S.; Walsh, S.J. and **Campana, S.E. (2003).** Age determination, validation and growth of Grand Bank yellowtail flounder (*Limanda ferruginea*). ICES J. Mar. Sci., **60**: 1123–1138.

Farrag, M.M.S.; Osman, A.G.M.; Mehanna, S.F. and **Osman, Y.A.A. (2018).** Fisheries status of the common species of family Mullidae in the Southern Red Sea, Hurghada, Egypt. Egypt. J. Aquat. Biol. Fish., **22**: 249–265.

Francis, R.I. (1988). Are growth parameters estimated from tagging and age-length data comparable? . Can. J. Fish. Aquat. Sci., **45**: 936-942.

Froese, R. (2006). Cube law, condition factor and weight--length relationships: history, meta-analysis and recommendations. J. Appl. Ichthyol., **22**: 241–253.

Gabr, M.H. and **Mal, A.O. (2017).** Stock assessment of the lizardfish Saurida tumbil (Bloch, 1795) in Jizan fisheries, Saudi Arabia. Egypt. J. Aquat. Res., **43**: 147–153.

GAFRD (General Authority for Fish Resources Development) (2020). Fisheries statistics yearbook. Cairo, Egypt: General Authority for Fish Resources Development.

Gompertz, B. (1825). On the nature of the function expressive of the law of human mortality and on a new mode of determining the value of life contingencies. Philosophical Transactions of the Royal Society of London, **115**: 515-585.

Hoenig, J.M. (1983). Empirical use of longevity data to estimate mortality rates. Fish. Bull., **82**: 898–903.

Hollander, M.; Wolfe, D.A. and Chicken, E. (2013). Nonparametric Statistical Methods. John Wiley & Sons.

Karkach, A.S. (2006). Trajectories and models of individual growth. Demogr. Res., **15**: 347–400.

Katsanevakis, S. and **Maravelias, C.D. (2008).** Modelling fish growth: multi-model inference as a better alternative to a priori using von Bertalanffy equation. Fish Fish., **9**: 178–187.

Kenchington, T.J. (2014). Natural mortality estimators for information-limited fisheries. Fish Fish., **15**: 533–562.

Kneebone, J.; Natanson, L.J.; Andrews, A.H. and **Howell, W.H. (2008).** Using bomb radiocarbon analyses to validate age and growth estimates for the tiger shark, *Galeocerdo cuvier*, in the western North Atlantic. Mar. Biol., **154**: 423–434.

Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). J. Anim. Ecol., 201–219.

Letourneur, Y.; Chabanet, P.; DurviLLe, P.; Taquet, M.; Teissier, E.; Parmentier, M.; Quero, J.C. and **Pothin, K. (2004).** An updated checklist of the marine fish fauna of Reunion Island, south-western Indian Ocean. Cybium, **28**: 199–216.

Mehanna, S.F. and **El-Gammal, F.I. (2007).** Gulf of Suez fisheries: current status, assessment and management. JKAU Mar. Sci., **18**: 3–18.

Mehanna, S.F.; Osman, A.G.M.; Farrag, M.M.S. and **Osman, Y.A.A. (2018).** Age and growth of three common species of goatfish exploited by artisanal fishery in Hurghada fishing area, Egypt. J. Appl. Ichthyol., **34**. https://doi.org/10.1111/jai.13590

Mohammad, A.S.; Mehanna, S.F.; Osman, Y.A.A. and **El-Mahdy, S.M. (2020).** Age, growth and population parameters of the spiny squirrelfish, *Sargocentron spiniferum* (Forsskål, 1775) from Shalateen fishing area, Red Sea, Egypt. Egypt. J. Aquat. Biol. Fish., **24**: 369–380.

Neumann, R.M.; Guy, C.S. and **Willis, D.W. (2012).** Length, weight, and associated indices. In Zale, A. V., Parrish, D. L., and Sutton, T. M., editors, Fisheries Techniques, Third Edition, chapter 14; 637-676. American Fisheries Society, Bethesda, MD.

Ogle, D.H.; Wheeler, P. and **Dinno, A. (2020).** FSA: Fisheries Stock Analysis. R package version 0.8. 30.9000.

Ogle, D.H. and **Winfield, I.J. (2009).** Ruffe length--weight relationships with a proposed standard weight equation. North Am. J. Fish. Manag., **29**: 850–858.

Ong, J.J.L.; Meekan, M.G.; Hsu, H.H.; Fanning, L.P. and **Campana, S.E. (2020).** Annual bands in vertebrae validated by bomb radiocarbon assays provide estimates of age and growth of whale sharks. Front. Mar. Sci., **7**: 188.

Osman, Y.A.A.; Mehanna, S.F.; El-Mahdy, S.; Mohammad, A.S. and **Mahe, K. (2020).** Age precision and growth rate of *Rhabdosargus haffara* (Forsskål, 1775) from Hurghada fishing area, Red Sea, Egypt. Egypt. J. Aquat. Biol. Fish., **24**: 341–352.

Pauly, D. (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES J. Mar. Sci., **39**: 175–192.

Pauly, D.; Cabanban, A. and **Torres, F.S. (1996).** Fishery biology of 40 trawl-caught teleosts of western Indonesia. ICLARM, 1996.- ISBN 971-8709-48-7. p. 135-216.

Pitcher, T. and Hart, P.J (1982). Fisheries Ecology. Santiago, J. 1993. A new length-weight relationship for the North Atlantic albacore. Collect. Vol. Sci. Pap, ICCAT, Chapman and Hall, London, **40**: 316-319.

Pope, K.L. (2007). Condition. Condition. Analysis and interpretation of freshwater fisheries data., 423-471.

Pradeep, H.D.; Shirke, S.S. and **Kar, A.B. (2014).** Age, growth, and mortality of *Amblygaster sirm* (Walbaum, 1792) from Andaman Waters. J. Andaman Sci. Assoc., **19**: 201–208.

Quinn, T.J. and **Deriso, R. 1999.** Quantitative Fish Dynamics. Oxford University Press, New York, New York. 542 pages.

Randall, J.E. (2005). Reef and Shore Fishes of the South Pacific. Univ. Hawai'i Press. Honolulu.

Richards, F.J. (1959). A flexible growth function for empirical use. Journal of Experimental Biology **10**: 290-300.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. Technical Report Bulletin 191, Bulletin of the Fisheries Research Board of Canada.

Ricker, W.E. (1979). Growth rates and models. Pages 677-743 In W.S. Hoar, D.J. Randall, and J.R. Brett, editors. Fish Physiology, Vol. 8: Bioenergetics and Growth. Academic Press, NY, NY.

Russell, B.C. and **Houston, W. (1989).** Offshore fishes of the Arafura Sea. Beagle: Records of the Museums and Art Galleries of the Northern Territory, The, **6**: 69-84.

Samy-Kamal, M. (2015). Status of fisheries in Egypt: reflections on past trends and management challenges. Rev. fish Biol. Fish., **25**: 631–649.

Schnute, J.T. (1981). A versatile growth model with statistically stable parameters. Can. J. Fish. Aquat. Sci., **38**: 1128-1140.

Sinovčić, G.; Franičević, M.; Zorica, B. and **Čikeš-Keč, V. (2004).** Length--weight and length-length relationships for 10 pelagic fish species from the Adriatic Sea (Croatia). J. Appl. Ichthyol., **20**:156–158.

Tesch, F.W. (1971). Age and Growth. Methods Assessment of Fish Production in fresh waters. (W. E. Ricker , ed.) IBP Handbook 3 , Blackwell, Oxford. 98–130.

Then, A.Y.; Hoenig, J.M.; Hall, N.G. and **Hewitt, D.A. (2015).** Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES J. Mar. Sci., **72**: 82–92.

Von Bertalanffy, L. (1938). A quantitative theory of organic growth (inquiries on growth laws. II). Human biol., **10**:181-213.

Wege, G.W. and **Anderson, R.O. (1978).** Relative weight (Wr): A new index of condition for Largemouth Bass. In Novinger, G. D. and Dillard, J. G., editors, New Approaches to the Management of Small Impoundments. Am. Fish. Soc., Special Publication., 5: 79- 91.