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Population dynamics of the Egyptian Sole *Solea aegyptiaca* Chabanaud, 1927 (Osteichthyes: Soleidae), in Qarun Lake, Egypt

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Abstract
Aspects of population dynamics of *Solea aegyptiaca*, which is considered one of the most important commercial fish species in Egypt fisheries, the sample was collected monthly between January 2015 to December 2015 from landing sites. Age and growth studies based on otolith reveals that the relatively fast growth occurs at maximum age of 4 years. The back-calculated total length range from 15.29 cm at age I to 27.12 cm at IV years. Growth was described by Von-Bertalanffy model as $L_t = 28.60(1\text{-}e^{-0.563(t+0.350)})$ and $W_t = 186.31\ (1\text{-}e^{-0.563(t+0.350)})^{2.932}$. Estimates of total, natural, and fishing mortality were 1.10, 0.29, and 0.81 year^{-1}, respectively. The value of exploitation rate (E= 0.74) indicates that the species is suffering from high fishing pressure.

Keywords: Qarun Lake, *Solea aegyptaica*, Soleidae, Age and growth, population dynamics

1. Introduction

Commercial species *Solea* are the flat fisheries production from the fishing ground of Qarun Lake. It can be also considered as an important element of fisheries in various countries around the Mediterranean Sea and East of Atlantic Ocean. Although *Solea* species are economically highly important, only limited numbers of studies are available and there were no enough basic studies to establish a management plan based on age and growth, mortality rate, and reproduction. Qarun Lake is considered one of the oldest Egyptian Lakes, a remaining spot of Morris Lake. This Lake is characterized by significant geological formation; it is an inland Lake that does not related to the sea. Located about 95 Km South-West Cairo in northern Fayoum governorate between longitude 30° 25\ and 29° 32\ N, figure (1). There are about 11 main landing sites in Qarun Lake, total production is about 4518 tons (0.30%) of the Egyptian total production. *Solea aegyptiaca* is one of the most commercial species where *Solea* contributes about (24.59%) from the Qarun lake fisheries total production [1]. *Solea* species are highly important to the Egyptian fisheries economy. There are some studies made for *Solea* species [2]. studied stock assessment and management of *Solea* in South-Western Mediterranean coast [3], studied the biological parameter trend of Qarun Lake ecosystem [4]. studied population dynamics of *Solea aegyptiaca*at Bardawil lagoon, and Mediterranean coast of Sinai, Egypt. The present study was carried out to discuss and estimate the basic parameters required for population dynamics of the *Solea aegyptica* at Qarun Lake, to gain more necessary information for the management and development of this important species.

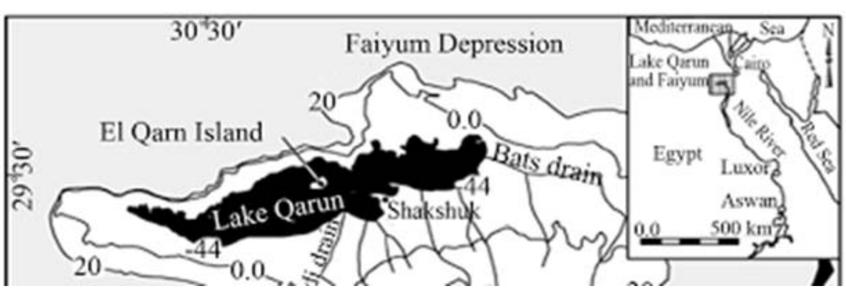

Fig 1: map of Qarun Lake

2. Material and methods

The study was carried out in the major landing site of Qarun Lake coast. 573 both sexes combined of *Solea aegyptiaca* were collected monthly between January to December, 2015. The measurements recorded for each specimen are: total length to the nearest 0.1 cm, total weight to the nearest 1gm.

For age determination the otoliths of *Solea aegyptiaca* were cleaned by 5% (NH4OH) solution, to remove any attached tissues, washed in distilled water, dried and immersed in clove oil, then examined using optical system consists of "Nikon Zoom stereomicroscope focusing block, heidehain's electronic bidirectional read out system VR X 128", under transmitted light. The total radius of each otolith "R" (the distance from the focus to the margin) as well as the distance from the focus of the otolith to the successive annual were measured to the nearest 0.01 mm. The body length-otolith radius relationship was determined by mean of the least square regression. The length at the end of each year of life were back-calculated from otolith measurements using equation [5].

2.1 Length – Weight relationship

The relationship between length and weight was described by the potential equation ($W = a\ L^n$), [6]. Where W is the total weight (g), and L is the total length (cm), a and n the constant. The coefficient of determination (r^2) was used as an indicator of the quality of the linear regression [7].

The condition factor or the coefficient of condition was calculated by tow different methods

1- [8] condition factor "Kc".

$Kc = 100\ (W/L^3)$

2- Relative condition factor "Kn"

$Kn = W/W^{/}$

Where "W" is the observed weight in gram and "$W^{/}$" is the calculated weight in gram.

2.2 Mortality rate

Total mortality (Z) was estimated by the linearzed catch curve method by [9] which based on the analysis of Length – frequency data. The natural mortality coefficient M was estimated using the method of Alverson and Carney as: $M = 3 * K / [\exp(tmax * 0.38 * K) - 1]$, where tmax is the age of the oldest fish while the fishing mortality coefficient was $F = Z - M$ and the exploitation rate E was $E = F/Z$.

2.3 The back – calculated

The back calculated lengths were used to estimate the growth parameter of the Von Bertalanffy growth model $Lt = L\infty(1 - e^{-k\ (t\text{-}t0)})$ by fitting the [10, 11] plot. While (t_0) was estimated by the equation $T_0 = t + 1/k\ \ln(L\infty - L_t) / L\infty$. The back – calculated weight at the end of each year was estimated by length – weight equation.

The growth performance index (φ) was computed according to the formula of [12] as $\varphi = \text{Log } K + 2 \text{ Log } L\infty$.

2.4 Mathematical models of growth

The models, [13, 14] $Lt = L\infty\ (1 - e^{-k(t\text{-}t0)})$ was used to describe growth in size, where, Lt is the length at age t, L∞ the asymptotic length, K the body growth coefficient and defines the growth rate towards L∞ and t_0 the hypothetical age at which a fish would have zero length. The values of L∞, K and t_0 were estimated by plotting Lt VS Lt+1 using the [13-15].

2.5 Reproduction

The length at first sexual maturity L_{50} (the length at which 50% of fish reach their sexual maturity) was estimated by fitting the maturation curve between the observed points of mid – class interval and the percentage maturity of fish corresponding to each length, interval. Then L_{50} was estimated as the point on the X – axis corresponding to the 50% point on the Y – axis. The length at first capture L_c was estimated by the analysis of catch curve as described by [16].

3. Results

3.1 Length – Weight relationship

The observed total length of 573 *Solea aegyptiaca* caught from Qarun coast between January to December, 2015 ranged between 10.6 and 27.5 cm and total observed weight between 10.2 and 175 g. The length – weight relationship (Fig. 2) is described by the equation: $W = 0.01\ L^{2.932}$ ($r^2 = 0.946$). Isometric growth was observed.

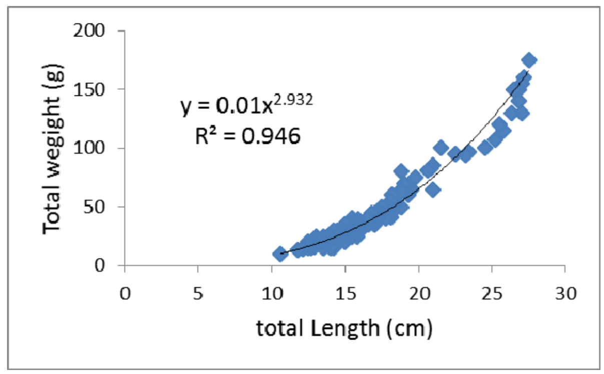

Fig 2: Length-weight relationship for combined sexes of *Solea aegyptiaca* for Qarun Lake (2015).

3.2 Body Length – Otolith Relationship

573 specimens were collected by ageing growth analysis. Estimated age ranged between 0 – 4 year. The mean fish length and average otolith radius per each length group is described by relating the fish length to the otolith radius size (Fig. 3). The relationship between total length and otolith shows a linear trend on the scattered diagram, described by the equation: $L= 0.013 + 0.113y$ and $r^2 = 0.748$.

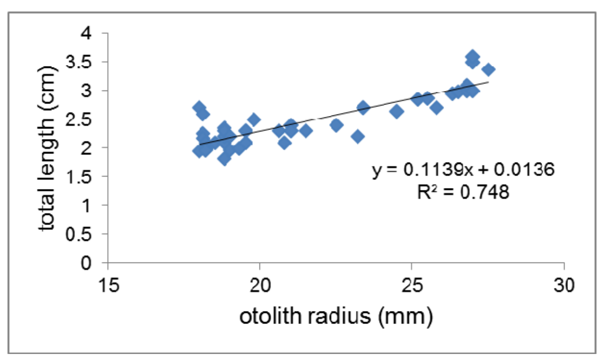

Fig 3: Relationship between the total length and the otolith radius of *Solea aegyptiaca* (combined sexes) for Qarun Lake (2015).

3.3 The back – calculations

The average back – calculation length and annual increment of the combined sexes (Table 1) are 15.43, 5.87, 2.91 and 2.14 cm for age I, II, III, and IV respectively. The highest annual increment occurred during the first year of life, while a noticeable decrease is observed in the four year, reaching minimum value during the fourth year of life. In the same Table (1), back – calculated weight at the end of each year of life of *Solea aegyptiaca* were estimated by applying the length – weight relationship. The results in the Table (1) shows that the maximum value of annual weight increases successively and reaches its maximum at the end of second group of life.

Table 1: Back-calculated length and weight relative to different age groups for combined sexes of *Solea aegyptiaca*.

Age group	Number of fish	Obs. Length (cm)	Back-cal. Length (cm)	Obs. Weight (g)	Back-cal. Weight (g)	Increment for length	Increment for weight	%
I	276	15.29	15.43	32.2	31.28	15.43	31.28	48.17
II	174	23.4	21.30	96	103.68	5.87	72.4	30.37
III	90	26.13	24.21	135.9	143.10	2.908	19.42	15.71
IV	33	27.12	26.34	150	159	2.135	15.9	5.759
Total	573							100

3.4 Condition factor (K)

Fig. (4) Shows the mean absolute condition factor (Kc) corresponding to the group length in male, female and combined sexes. For both sexes (Kc) values have the same trend. For males, in group length 21 cm, it slightly decreases from 1.10 cm in group length 21 cm to 0.9 in group length 22 cm, For female, it increases to 1.08 in group length 17 cm and decreases to 1.21 in group length 20 cm and settle Down at 0.98 in group length 21 cm. The relative condition factor (Kn) for males was estimated, it increases from 0.8 in group length 18 cm to 0.94. In female, it increases from 0.8 in group length 18 cm to 0.94 in group length 19 cm. In combined sexes, it increases from 0.8 in group length 18 cm to 0.94 in lengths group 19 cm. On the other hand, it decreases 0.75 in group length 21 cm Fig. (5).

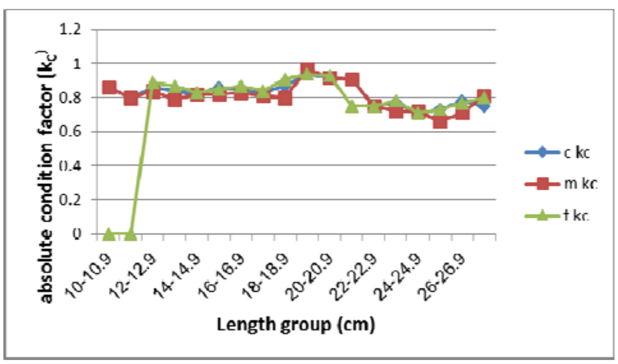

Fig 4: Mean absolute condition factor (K_C) for male, female and combined sexes of *Solea aegyptiaca* according to the length in Qarun Lake, season (2015)

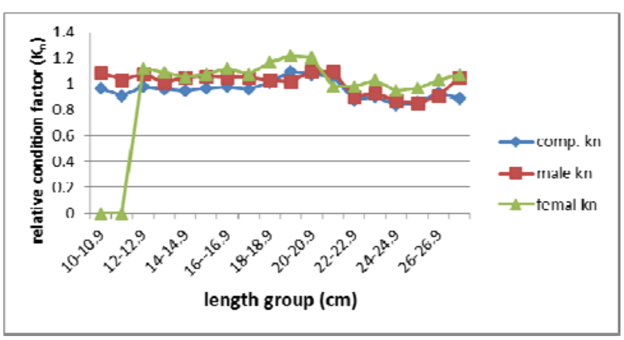

Fig 5: Mean relative condition factor (K_n) for male, female and combined sexes of *Solea aegyptiaca* according to the length in Qarun Lake, season (2015)

3.5 Growth parameters

The parameters of Von-Bertalanffy growth were calculated as $L\infty$ = 25.60 cm, K = 0.563 yr^{-1} and T_0 = - 0.350 and the obtained equation was: $Lt = 28.60\ (1 - e^{-0.563\ (t + 0.350)})$ for the length growth. $Wt = 186.31\ (1 - e^{-0.563(t + 0.350)})^{2.932}$ for the weight growth. The *Solea aegyptiaca* growth performance index is approximately 2.7.

3.6 Mortality and Exploitation Rate

The total natural and fishing mortality coefficient of *Solea aegyptiaca* from Qarun Lake shows in Fig. (6). It was clear from the obtained data that the value of Z, M and F were 1.10, 0.29 and 0.81 $year^{-1}$ respectively. From cumulated catch curve (Fig. 7) based on the length composition data of *Solea aegyptiaca* in Qarun Lake, exploitation rate (E) was computed as 0.74 as recorded by [17].

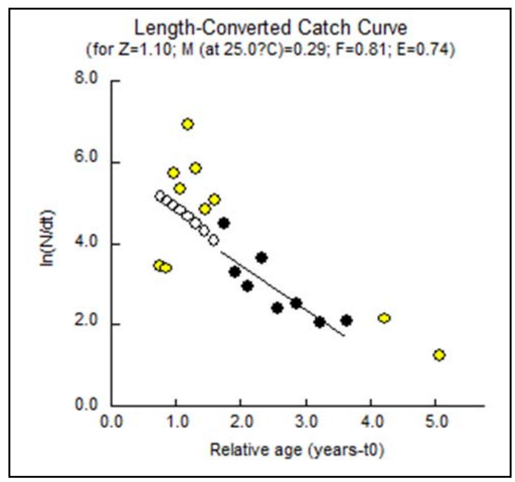

Fig 6: cumulated catch curve based on length composition data of *Solea aegyptiaca* from Qarun Lake season 2015.

4. Discussion

In flat fishes, the use of otolith as an accurate method of age determination has been early accepted. In the present study, otoliths of *Solea aegyptiaca* were used for age determination and were proved to be the most valid structure for this purpose. The same results were recorded by several authors. [18, 19, 2, 21]. The validity of the growth studies using otolith is based on the number of annual rings formed on the otolith. The relationship between the otolith radius and the total length was found to be linear and does not pass through the origin and can be represented by the following equation: L = 0.018 + 0.113y and r^2 = 0.748. The values resulting from relating the otolith radius and the fish body length were involved in the back – calculations of length at the end of each year of life. The mean length of the fish combined sexes at the end of various life stages were 15.43, 5.87, 2.91 and 2.14 cm for the age groups from I to IV respectively. Based on this results it is clear that, the highest growth length rate of *Solea aegyptiaca* from Qarun Lake is found to be at the end of the first group of life, after which the annual increment in length decreases with the age increase. The growth pattern was also observed by several authors. [20] Reported that in Bardawil Lagoon the growth rate in length of *Solea solea* was rapid in the first year of life and decreases with further increase in age. The same trend was observed by [22] in Abo – Kir Bay. Also, [2] found that the length growth rate of *Solea aegyptiaca* in Port Saaid region was rapid in the first year of life, [23] studied the growth of *Solea Solea* from the North Sea and concluded that, the fish reached 10.0 cm by the end of first year of life. In the present study, back – calculation weight at the end of each year of life for *Solea aegyptiaca* shows that the maximum value of the annual weight increase reaches its maximum at the end of the second group of life. The same observation came with the results of [24], she found that the calculated weight for *Solea aegyptiaca* reaches its maximum at the end of the second group of life. The coefficient condition factor (k) is another way to relate the fish lengthand weight. The condition factor gives an idea about the relative robustness of the fish, fatness, and it's well being degree. This factor is based on a hypothesis relating the fish length to its condition. In the present study, the obtained results indicate that, there is no significant trend in the value of Fulton's condition factor (Kc) within the male length group, female and combined sexes. The relative condition factor (kn) for each length group for male, female and sexes combined. The value of (Kn) was larger in males of bigger size (0.94). The same increase in (Kn) occurs with females of size (0.94). However, in combined sexes it decreases to (0.75) in length of 21 cm. various authors studied the length – weight relationship of flat fish in different regions. [25] Computed the relation between the length and weight of *Eopsette grigorjgewi* from south – western Japan Sea and concluded that the Power "b" is equal to 3.02 for males and 3.21 for females. [25] Concluded that length – weight relationship of the winter flounder, the power "b" is equal to 3.10 and 3.01 respectively for males and females. [22] estimated that the biology of *Solea vulgaris* in Abo–Kir Bay, the power "b" is equal to 2.903 for males and 2.82 for females. In the present study, the length – weight relationship (Fig. 2) was described by the equation: $W = 0.01L^{2.932}$ ($r^2 = 0.946$), the value of the power "b" as shown above was equal to "2.932" for combined sexes. This reflects the stability in the both proportions and specific gravity of *Solea aegyptiaca* during its life span for both males and females. These results are disagreeing with [20], with *Solea solea*in Bardawil Lagoon. Close to [22], which found (b = 2.825 in *Solea Vulgaris* in Abo – Kir Bay. The results disagreed with [25, 26, 20]. In the present study, the Von Bertalanffy model was used to describe the theoretical growth of *Solea aegyptiaca* from Qarun Lake. The constants of the model were estimated by using three methods: [10-11, 27-28]. The estimated equations, for growth in length $L_t = 28.60\ (1 - e^{-0.563\ (t+0.350)})$ and for growth in weight $W_t = 186.31\ (1 - e^{-0.563(t+0.350)})^{2.932}$ The values of growth parameters ($K = 0.563\ yr^{-1}$), ($T_0 = -\ 0.350$) and ($L\infty = 28.60$ cm). The body growth coefficient ($K = 0.563 yr^{-1}$) is higher than *Solea solea* in Bardawil Lagoon [20]. It is well know that, the growth coefficient, "K" is inversely proportional to fish life. In the present study, *Solea aegyptiaca* in Qarun Lake is characterized by high growth coefficient (0.56) and has a shorter life span (only four years), than that in *Solea solea* in Bardawil Lagoon [20] and in *Solea aegyptiaca* in Port said coast [2, 29]. studied the age and the growth of common *Solea* (*Solea vulgaris*) on the French Atlantic coast the mentioned that, there is a significant differences in growth between males and females of *Solea vulgaris*. Males have higher "K" (0.37) and smaller L∞ (45.5 cm), while females have lower "K" (0.27) and lives longer with L∞ (51.13 cm). The natural mortality coefficient (M) was estimated using the method of Alverson and Carney. It was 0.29 per year for *Solea aegyptiaca* Qarun Lake. These results are higher than *Solea solea* in Bardawil Lagoon 0.21 per year for combined sexes observed by [20, 30] for North Sea Plaica 0.20 per year. However, it was lower than North Sea *Solea solea* (0.65) by [31]. The estimated fishing mortality of *Solea agyptiaca* in Qarun Lake was 0.81 per year. It was lower than the fish mortality of *Solea solea* in Bardawil Lagoon ($1.054\ yr^{-1}$) obtained by the natural mortality ($0.29\ yr^{-1}$) versus fishing mortality ($0.81 yr^{-1}$) observed for *Solea aegyptiaca* indicated the imbalanced position of the stock [32], suggested that, fishing mortality should be about equal to natural mortality, resulting in an exploitation rate of $0.5\ yr^{-1}$. However, exploitation rates should be very conservative for relatively long lived species [33]. The current established exploitation rate was 0.74 (E = 74%). The current exploitation rate is over exploited stock. These results are disagreeing with [32]. He reported that the current exploitation rate is optimally exploited stock (50%), fig. (7) Resulted over exploitation rate in this study.

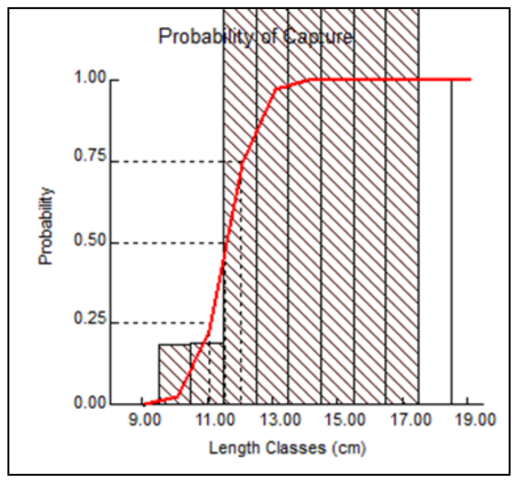

Fig 7: Length of fish at 50% at that size is vulnerable to capture of *Solea aegyptiaca* Qarun Lake.

The length at first capture (the length at which 50% of the fish at the size are vulnerable to capture) was estimated as a component of length – converted catch curve analysis. The value obtained was 11 cm, (Fig. 7), it was less than L50. We recommend that the *Solea aegyptiaca* in the Qarun Lake fishery is in a situation of overexploitation, so reducing the exploitation rates and increasing the length of first capture (related to mesh size), will be associated with a decrease in the yield per recruit. It is necessary to replenish the blood of these fish by moving mothers from different fish sources to break the inbreeding phenomenon that affects the growth of these fishes, which affects the reconstruction and measurements of growth in length and weight of the fish compared to the same species in other places such as Bardawil Lagoon and Mediterranean Sea. Qarun Lake is a closed lake thatdoes not have a connection to the sea, and that causes the emergence of the phenomenon of dwarfism.

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