

Critical lengths, mortality rates and relative yield per recruit of the common sole *Solea solea* from the Egyptian Mediterranean coast off Alexandria

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ABSTRACT

Mortality rates of the common sole *Solea solea* from Alexandria were estimated based on the von Bertalanffy growth parameters obtained by the same authors as $L_{\infty} = 34.77\text{cm}$; $K = 0.55\text{ year}^{-1}$ and $t_0 = 0.07\text{ years}$ for males, $L_{\infty} = 36.24\text{ cm}$; $K = 0.63\text{ year}^{-1}$, $t_0 = -0.01\text{ years}$ for females and $L_{\infty} = 35.1\text{ cm}$; $K = 0.58\text{ year}^{-1}$ and $t_0 = 0.003\text{ years}$ for sexes combined during two fishing seasons (2011-2013). The total, natural and fishing mortalities were 2.09, 0.52 and 1.57 year^{-1} respectively for males, 1.75, 0.53 and 1.22 year^{-1} respectively for females and 1.7, 0.52 and 1.18 year^{-1} respectively for sexes combined. Correspondingly, the exploitation ratio was $E = 0.75, 0.7$ and $0.69/\text{y}$ for males, females and sexes combined respectively. The estimated length at first capture L_c was 15.97, 12.72 and 14.22 cm for males, females and sexes combined, respectively while the length at first maturity L_m was 15.31, 15.87 and 15.98 cm for males, females and sexes combined, respectively. These results reflect the high level of the exploitation. The relative yield per recruit analysis showed that the stock of *S. solea* is over exploited and needs urgent management regulations to conserve this potential fishery.

Keywords: Alexandria; Soleidae, *Solea solea*, Mortality rates; per-recruit analysis; fisheries management.

INTRODUCTION

The Egyptian Mediterranean coast is about 1100 km, extending from El-Sallum in the West to El-Arish in the East. The fishing grounds along the Egyptian Mediterranean coast are divided into 4 regions: Western region (Alexandria and El-Mex, Abu-Qir, Rasheed, El-Maadiya, and Mersa Matruh), Eastern region (Port Said and El-Arish), Demietta region and Nile Delta region. The western region constitutes about 39% of the total catch from the Egyptian Mediterranean, from which Alexandria and El-Mex is the most productive fishing ground, providing up to 53% of the total fish production in the western region (GAFRD annual reports).

The common sole *Solea solea*, which locally is known as Mousa is one of the most important commercial fish species in Alexandria coast. The soles assume a very important place in the Egyptian Mediterranean fisheries. Soles in the Egyptian Mediterranean are exploited mainly by trawling and a small part of catch is caught by kannar and trammel nets. The population parameters of the common sole in the Egyptian waters are sparsely studied specially in Alexandria region (El-Gammal *et al.*, 1995; Mehanna and Salem, 2012; Salman, 2014; Mehanna *et al.*, 2011, 2014 & 2015). So, the present study aims at determining the critical lengths, mortality and exploitation rates and relative yield per recruit of the common sole *Solea solea* in Alexandria as a basic parameters for its management.

MATERIALS AND METHODS

Growth parameters

Derived from Mehanna *et al.* (2015).

Critical lengths

Length at recruitment

The length at recruitment (L_r) was determined as the smallest sole specimen in the catch.

Length at first capture

The length at first capture (L_c); the length at which 50% of the common sole retained in the gear was estimated by the analysis of catch curve using the method of Pauly (1984).

Length at first sexual maturity

The length at first sexual maturity (L_m); the length at which 50% of sole reach their sexual maturity was estimated by fitting the percentage maturity against mid lengths. L_m was estimated as the point on X-axis corresponding to 50% point on Y-axis.

Mortality and exploitation rates

Total mortality coefficient (Z) was estimated as the geometric mean of three different methods; Ricker (1975), Jones and Van Zalinge, (1981) and Pauly, (1983), while the natural mortality coefficient (M) was estimated as the geometric mean of the methods; Tanaka (1960), Ursin (1967) and Pauly (1980). The fishing mortality coefficient was estimated by subtracting the value of natural mortality coefficient from the value of total mortality coefficient as follows: $F = Z - M$ and the exploitation ratio was estimated by the formula suggested by Gulland (1971) as $E = F/Z$.

Relative Yield per Recruit (Y/R)'

The relative yield per recruit (Y/R)' and the relative biomass per recruit (B/R)' were estimated by using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986) and incorporated in FiSAT software.

RESULTS AND DISCUSSION

Growth parameters

The von Bertalanffy theoretical growth in length equations for *S. solea* from Alexandria waters of Mediterranean are obtained from Mehanna *et al* (2015) as:

$$\text{Males } L_t = 34.77 (1 - e^{-0.55 (t - 0.06926)})$$

$$\text{Females } L_t = 36.24 (1 - e^{-0.62 (t - 0.00955)})$$

$$\text{Sexes combined } L_t = 35.81 (1 - e^{-0.58 (t + 0.00295)})$$

Where L_t is the length at age t

Critical lengths

Length (L_r) at recruitment

The smallest total length in the length frequency distribution of *S. solea* from Alexandria waters was 13.4 and 11.9 cm for males and females, respectively. These lengths are considered as the estimates of the length at recruitment.

Length (L_c) at first capture

The length at first capture (the length at which 50% of the fish at that size are vulnerable to capture) was estimated from the catch curve of Pauly (1984). The resultant curve derived from the catch curve provided an estimate of L_c at 15.97, 12.72 and 14.22 cm for males, females and sexes combined, respectively (Fig.1).

Length (L_m) at first sexual maturity

Length at first sexual maturity (L_m) has a great importance in the determination of optimum mesh size. From the maturation curve, the length at first sexual maturity of *S. solea* from Alexandria was 15.31, 15.87 and 15.98 cm for males, females and sexes combined, respectively. It is obvious that males matured at a slightly smaller size than females, and the estimated length at first capture was smaller than L_m . This means that the exploited *S. solea* must be protected in order to share the spawning activities at least once before being fished. Therefore, the mesh sizes used should be increased to catch fish of lengths greater than 17 cm. These results are similar to the findings of Mehanna and Salem (2012) and Salman (2014) for the same species in Bardawil Lagoon.

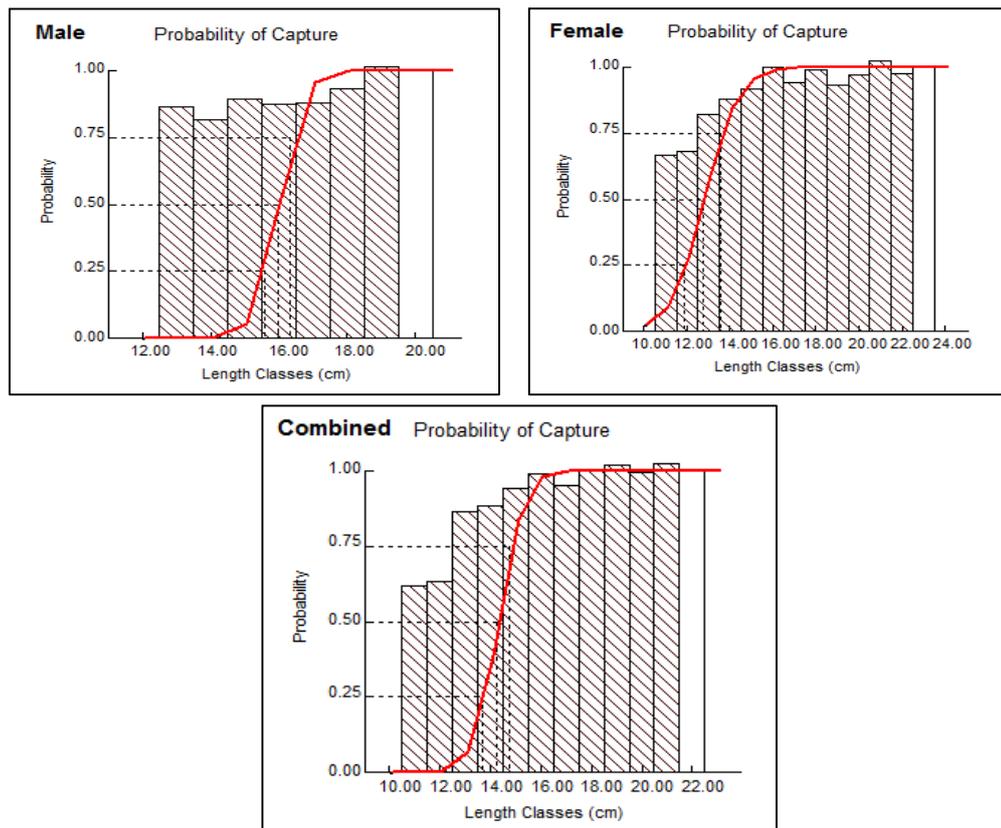


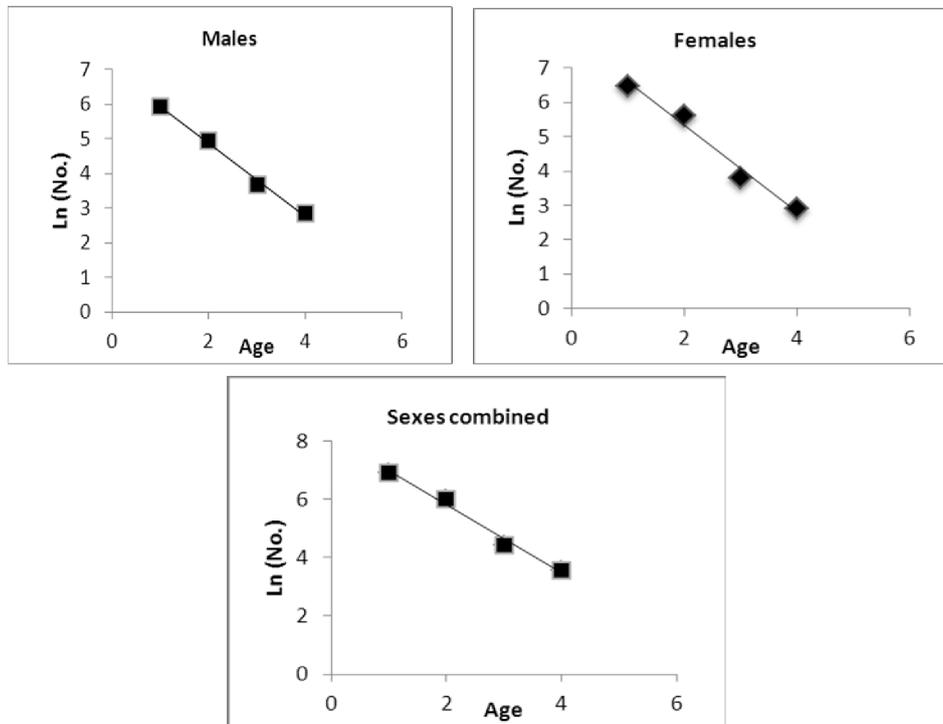
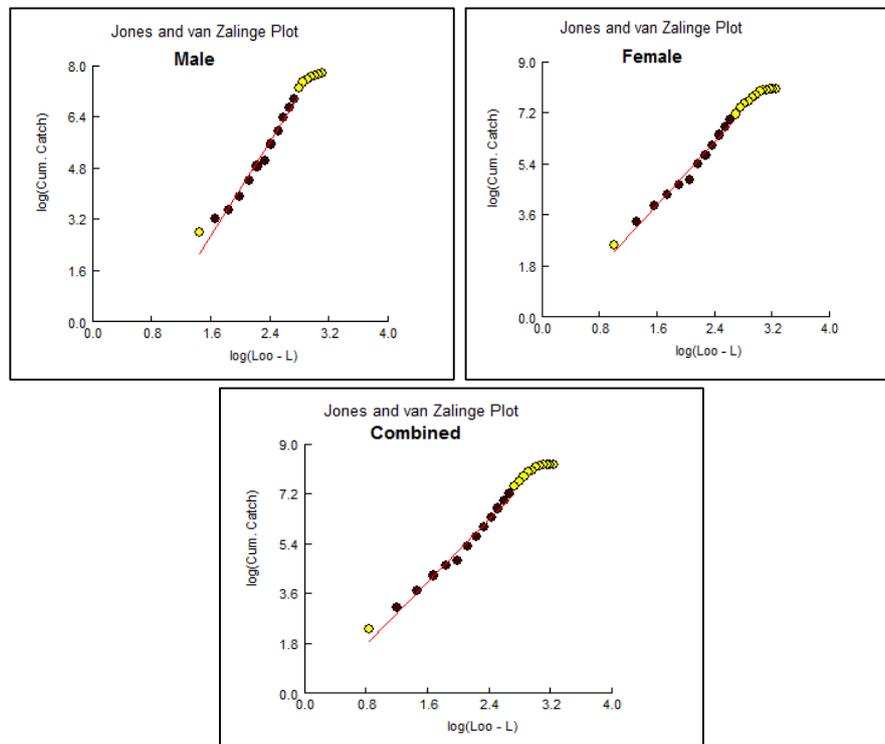
Fig. 1: Length at first capture of *Solea solea* from Alexandria.

Mortality and exploitation rates

The total mortality coefficient Z was estimated using three different methods and the results are summarized in Table (1) and represented in Figures (2, 3 and 4). It is clear that, the Z -values obtained from the three different methods are nearly the same, so the geometric mean of the three values will be used in the subsequent calculations. While, the geometric means of the three used methods for natural mortality M estimation of *S. solea* were 0.52, 0.53 and 0.52/year for male, female and sexes combined respectively. It is obvious that, females are characterized by slightly higher M -value than males. Based on these values, the fishing mortality coefficient F were 1.57, 1.22 and 1.18/ year for males, females and sexes combined respectively. It is clear that, males of *S. solea* have higher fishing mortality rate than females.

Table 1: Z estimation from the different methods for *Solea solea* from Alexandria.

Method	Males	Females	Sexes combined
Ricker (1975)	1.89	1.61	1.61
Jones & van Zalinge (1981)	2.02	1.73	1.69
Pauly (1983)	2.38	1.92	1.82
Geometric Mean	2.09	1.75	1.70

Fig. 2: Semi-logarithmic regression of *Solea solea* from Alexandria.Fig. 3: Cumulated catch curve of *Solea solea* from Alexandria.

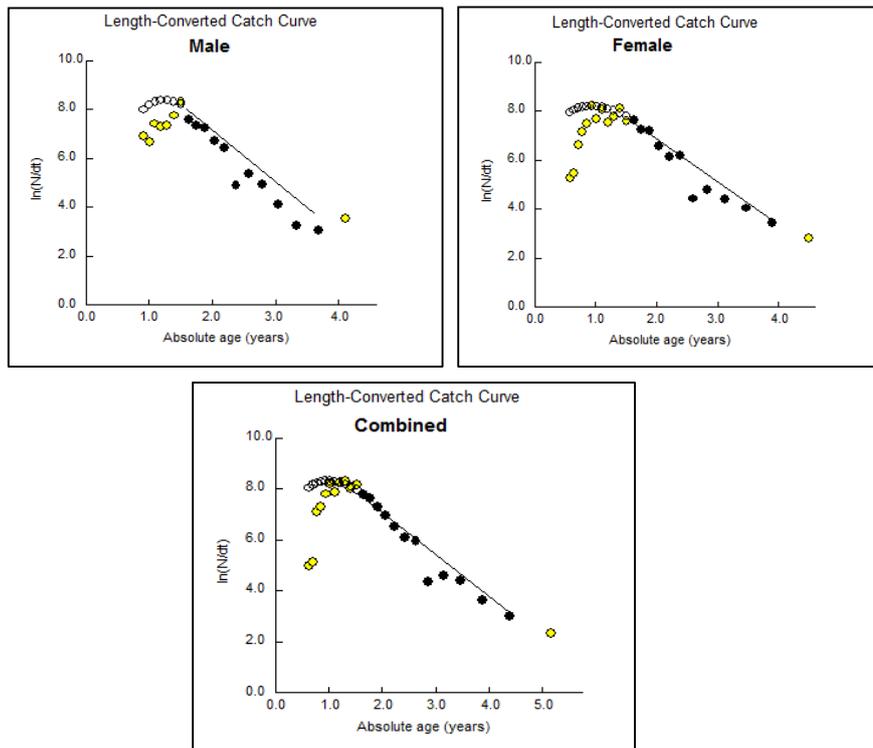


Fig. 4: Converted catch curve of *Solea solea* from Alexandria.

Exploitation ratio (E)

The estimated exploitation ratio for *S. solea* were 0.75, 0.70 and 0.69 / year for males, females and sexes combined respectively, which seemed to be higher than the optimum level of exploitation ($E = 0.5$). From results, both of fishing mortality and exploitation rate were high indicating the high level of exploitation.

These results are in agreement with the previous studies dealing with the mortality and exploitation ratio of *S. solea* in the different Egyptian waters (Mehanna, 2007; Mehanna and Haggag, 2010; Mehanna *et al.*, 2011; Mehanna and Salem, 2012; Mehanna *et al.*, 2013 and Salman, 2014).

Relative Yield per Recruit (Y/R)'

The relative yield per recruit of the sexes combined of *S. solea* was estimated and the results are represented graphically in Fig. (5). The results showed that, the current exploitation rate ($E = 0.69/y$), length at first capture ($L_c = 14.22$ cm) and natural mortality coefficient ($M = 0.52/y$) didn't achieve the maximum relative yield per recruit, and the maximum yield per recruit is obtained at exploitation rate ($0.58 / y$) which is lower than the current E by 15%.

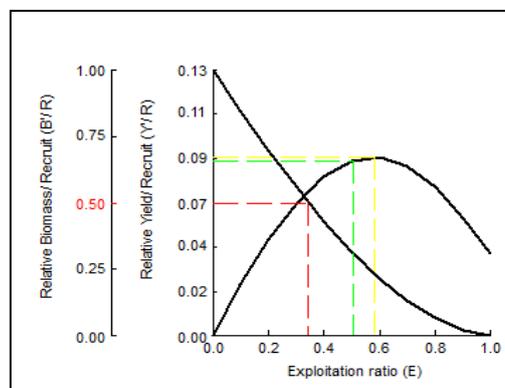


Fig. 5: Per-recruit analysis of *Solea solea* from Alexandria.

This means that the present level of fishing mortality ($F = 1.18/\text{year}$) was much higher than that gives the maximum $(Y/R)'$.

Both of $E_{0.1}$ (the level of exploitation at which the marginal increase in yield per recruit reaches 1/10 of the marginal increase computed at a very low value of E) and $E_{0.5}$ (the exploitation level which will result in a reduction of the unexploited biomass by 50%) were estimated. The obtained values of $E_{0.1}$ and $E_{0.5}$ were 0.5 and 0.35 respectively. The results indicated that the present level of E (0.69) is higher than the exploitation rate ($E_{0.5}$) which maintain 50% of the stock biomass. This means that the present level of the exploitation should be decreased by about 49%.

To evaluate the variation in yield per recruit due to change in the length at first capture (L_c) which is related to the estimation of optimum mesh size, the yield per recruit of *S. solea* was calculated by using length at first capture equal to 16 cm (\approx length at first sexual maturity) (Fig. 6). The figure showed that the maximum $(Y/R)'$ was obtained at $E_{MSY} = 0.61$ which is nearly the same as the current one. Both of $E_{0.1}$ and $E_{0.5}$ were estimated. The obtained values of $E_{0.1}$ and $E_{0.5}$ were 0.52 and 0.36 respectively. This means that, the present level of L_c is not the optimum L_c of this fish species and it must be about 16 cm.

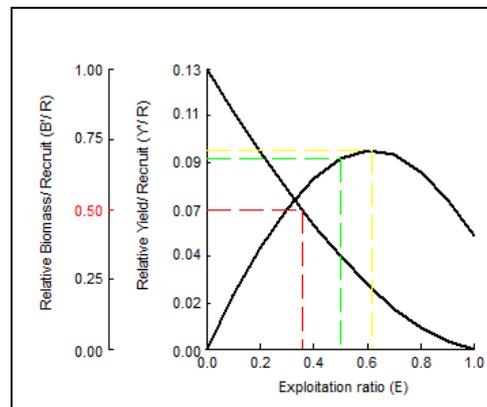


Fig. 6: Per-recruit analysis of *Solea solea* from Alexandria using $L_c = L_m$.

Conclusion and recommendations

The results showed that the stock of *S. solea* at Alexandria was overexploited. For the management purpose, the current exploitation rate must be reduced from 0.69 to 0.36. This means that the present level of exploitation should be decreased by about 49% to maintain a sufficient spawning biomass as well as the length at first capture should be raised from 14.2 cm to about 16 cm.

Accordingly, it should be control mesh size of nets used, control gear types used, protecting the spawning stock through implementing marine protected areas or closed seasons during the spawning, continue the study to assess and manage the different fish stocks exploited by trawling. Finally, the fisheries recording system should be improved.

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ARABIC SUMMARY

الاطوال الحاسمة ومعدلات النفوق والانتاج النسبي لكل جيل لاسماك موسى الشائعة (سوليا سوليا) في البحر المتوسط بسواحل الاسكندرية - مصر

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تعتبر اسماك موسى من اهم الاسماك الموجودة في البحر المتوسط في مصر التي تُصاد بحرفة الجر. ويوجد على الاقل ٥ انواع من اسماك موسى في مياه البحر المتوسط بمصر، اهمها اسماك موسى الشائعة (السوليا سوليا) و اسماك موسى المصرية (سوليا ايجيبتياكا). وتسمى اسماك موسى الشائعة (سوليا سوليا) محليا باسمك موسى وتعتبر واحدة من اهم الانواع الموجوده في سواحل الاسكندرية. بحساب مقاييس النمو لكل من الذكور والاناث والجنسين معا باستخدام النموذج الرياضى (فون برتلانفى)، تم حساب معدل النفوق الكلى ومعدل النفوق الطبيعى وكذلك معدل النفوق الناتج عن جهد الصيد وكان 2.09 و 0.52 و 1.57 (لكل عام) وذلك بالترتيب بالنسبة للذكور و 1.75 و 0.53 و 1.22 (لكل عام) وذلك بالترتيب بالنسبة للاناث و 1.7 و 0.52 و 1.18 (لكل عام) وذلك بالترتيب بالنسبة للجنسين معا وتم حساب معدل الاستغلال وكان 0.75 لكل عام بالنسبة للذكور و 0.7 لكل عام بالنسبة للاناث و 0.69 لكل عام بالنسبة للجنسين معا وبتعين الطول عند أول مصيد وكذلك الطول عند أول نضوج جنسى وجد أن الطول عند أول نضوج جنسى يفوق الطول عند أول مصيد وذلك لان غالبية أسماك موسى يتم صيدها قبل بلوغها مرحلة النضوج الجنسى لها مما كان له أكبر الأثر فى تدهور الطاقة الانتاجية لها وبتحديد الطول الأمثل عند أول مصيد والمرتبط بتعيين الماجات المناسبة للشباك المستخدمة وجد أنه ١٦ سم (الحالى 14.22 سم) كما وجد أنه للحفاظ على المخزون والوصول به للتنمية المستدامة يجب خفض معدل الاستغلال والمرتبط بمجهود الصيد الى نصف معدله الحالى تقريبا.