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FULL LENGTH ARTICLE

Capture production and stock assessment of *Solea aegyptiaca* Chabanaud, 1927 (Soleidae: Pleuronectiformes) in Bardawil Lagoon, Egypt

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Abstract Capture production from Bardawil Lagoon was described and analyzed. Fish samples of *Solea aegyptiaca* were collected for growth study. Otoliths were extracted from each specimen and used for age determination. Back-calculated lengths-at-ages were estimated and used to determine growth rates in length and weight. The von Bertalanffy growth parameters; L_∞, K and t_0, were determined. Growth in length could be described by the von Bertalanffy growth equation "VBGE": $L_t = 37.52\ [1 - e^{-0.42(t+0.4)}]$. The total mortality coefficient 'Z', the natural mortality coefficient 'M' and the fishing mortality coefficient 'F' were estimated to be 2.35, 0.63 and 1.72 year^{-1}, respectively. The current exploitation rate 'E_{cur}' was 0.73 year^{-1}. Beverton and Holt's relative yield per recruit Model (1966) was used to estimate the relative yield and biomass per recruit of *S. aegyptiaca* in Bardawil Lagoon. The yield-based biological reference points E_{max} and $E_{0.1}$ were determined and found to be 0.717 year^{-1} and 0.62 year^{-1}, respectively. Results indicated that the stock of *S. aegyptiaca* in Bardawil Lagoon is currently over-exploited. The current exploitation rate should be decreased to the widely adopted target reference point, $E_{0.1}$ = 0.62 year^{-1} for sustainable fishery production of *S. aegyptiaca* in Bardawil Lagoon.

1. Introduction

The Egyptian sole *Solea aegyptiaca* is one of the flatfish species of the family Soleidae which are of commercial importance in the Mediterranean Sea. It has been recently predicted to be a valid species (Vachon et al., 2008; Boukouvala et al., 2012) and is not a synonym of the common sole *Solea solea* as reported by Ben-Tuvia (1990) and Borsa and Quignard (2001).

Soles production represents an important part of the commercially exploited marine species in Bardawil Lagoon which

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is situated along the northern coast of Sinai, Southeast Mediterranean (Fig. 1). The Lagoon was built for utilizing fish resources that originate from the adjacent Mediterranean Sea. It covers an area of about 650 km^2, with depths ranging from 0.5 to 1.5 m and rare depths of 3 m. Many authors studied the fish production, fishery biology of many fish species and crustaceans and fisheries management of Bardawil Lagoon (Ben-Tuvia, 1984; El-Gammal et al., 1994; Abdel-Hakim et al., 1997; Abd-Alla, 2004; Ameran, 2004; Sabrah, 2004; Khalifa, 1995; Abdel-Razek et al., 2006).

Mehanna (2006) mentioned that a dramatic change occurred in the catch composition of the Lagoon during the last two decades, where the crustacean production increased and reached about 60% of the total catch in 2005, while the catch of economic fish species like sea bream and sea bass was reduced. She attributed this change in catch composition to many factors including: change in ecological conditions, increased salinity, continuous dredging (silting) of the Lagoon inlets, prohibition of the purse-seining in 1993, and introduction of shrimp trawl (called Kalsa).

Despite the economic importance of Soles in Bardawil Lagoon (their maximum catch was about 342.5 ton in 2008); only El-Gammal et al. (1994) estimated the yield per recruit of *S. solea* in the Lagoon. Mehanna (2007) described aspects of the population dynamics and stock status of the Egyptian sole *S. aegyptiaca* in the Southeastern Mediterranean coast off Egypt. Ahmed et al. (2010) studied the reproduction of *S. aegyptiaca* from Port Said in the Southeastern Mediterranean coast off Egypt. The present study aimed to describe and analyze the capture production of Soles compared to total capture production from the Lagoon during the last decade, determine age and estimate growth parameters, mortality coefficients, relative yield and biomass per recruit of *S. aegyptiaca* in Bardawil Lagoon. The values of E_{max} and $E_{0.1}$ were determined in order to evaluate the current stock status relative to these yield-based reference points.

2. Materials and methods

Total catch statistics (by species or species group) from Bardawil Lagoon during the period from 1996 to 2012 were obtained from the general authority for fish resources development (GAFRD) branch at the fish landing site of Eltelool. Fish samples of *S. aegyptiaca* were collected during the fishing season from May to December 2010. Measurements of total fish length and body weight were recorded for 445 specimens. The power equation: $W = a\,L^b$ was used to describe the relationship between fish length and body weight.

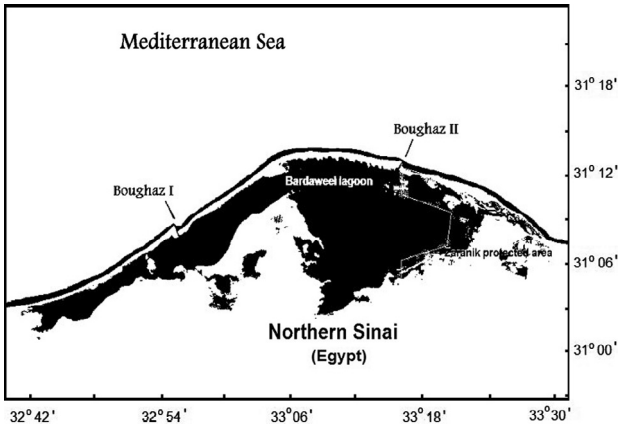

Figure 1 Map showing Bardawil Lagoon in Northern Sinai coast of the Mediterranean Sea, Egypt.

For age determination, the sagittal otoliths were removed from each specimen and preserved clean in an Eppendorf vial, containing water, with reference to the species name, date and serial number. The left-side otolith was examined using an optical system consisting of MEIJI Zoom Stereomicroscope connected to a computer system through digital video camera. Pictures were captured and saved by Micrometrics SE Premium software for measuring distance from the otolith focus to the outer margin and the margin of each annulus.

Back-calculated lengths-at-ages were estimated according to the Lee's equation (1920):

$$L_n = c + (L - c)s_n/S$$

where, L_n is the calculated length when the annulus 'n' was formed, L is the observed fish length, s_n is the distance in 'mm' from the otolith focus to the margin of the annulus 'n', S is the otolith radius (from the focus to the outer margin), c is the intercept of the linear regression analysis between the observed fish length (cm) and the otolith radius (mm) according to the linear relation: $L = c + d\,S$.

The von Bertalanffy Growth Equation (VBGE): $L_t = L_\infty[1 - e^{-K(t-t_0)}]$ was applied to describe growth in length of *S. aegyptiaca* in Bardawil Lagoon. The growth parameters; L_∞ and K were estimated by fitting Ford (1933) and Walford (1946) plot to the average back-calculated lengths-at-ages. The following equation described by Sparre and venema (1998) was used to estimate the value of t_0:

$$t_0 = t + 1/K\mathrm{Log}_e(1 - L_t/L_\infty).$$

The formula suggested by Pauly and Munro (1984); $\acute{o} = \mathrm{Log}\,K + 2\,\mathrm{Log}\,L_\infty$, was used to calculate the index of growth performance $\acute{o}$ for *S. aegyptiaca* in Bardawil Lagoon.

The instantaneous total mortality coefficient 'Z' was estimated by the Linearized length-converted catch curve method of Pauly (1983). The natural mortality coefficient 'M' was estimated by the Jensen (1996) equation: $M = 1.5\,K$. The difference between the total mortality coefficient 'Z' and the natural mortality coefficient 'M' was estimated to be the fishing mortality coefficient 'F'. The exploitation rate 'E' was estimated as the ratio E/Z. The length at first capture 'L_c' was determined graphically by the cumulative catch curve analysis as described by Pauly (1984).

The following model of Beverton and Holt (1966), modified by Pauly and Soriano (1986), was used to estimate the relative yield per recruit Y'/R and biomass per recruit B'/R of *S. aegyptiaca* in Bardawil Lagoon, applied in FiSAT II software and also in Excel worksheet:

$$Y'/R = EU^{M/K}\{1 - [3U/(1+m)] + [3U^2/(1+2m)] - [U^3/(1+3m)]\}$$

where,

$$U = 1 - (L_c/L_\infty), \quad m = (1-E)/(M/K), \quad \text{and } E = F/Z$$