Journal of Coastal Life Medicine

journal homepage: www.jclmm.com

Original article doi: 10.12980/jclm.4.2016J6-59

Fisheries management of round sardinella *Sardinella aurita* along North Sinai coast

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ARTICLE INFO

Article history:
Received 21 Mar 2016
Received in revised form 16 May 2016
Accepted 10 Jun 2016
Available online 5 Jul 2016

Keywords:
Eastern Mediterranean
Age and growth
Stock assessment
Fisheries management
Sardinella aurita

ABSTRACT

Objective: To estimate the biological and population parameters required for proposing a preparation to sustain and manage this valuable fish resource.
Methods: Aging was done by scales reading, and growth was estimated by using the back-calculation method. The values of growth parameters L_∞, k and t_o were calculated by von Bertalanffy model.
Results: The results of growth parameters L_∞, k and t_o were 28.36 cm, 0.184 per year and –0.8437 per year, respectively. Mortality coefficient, survival and exploitation rates estimated to perceive yield per recruit and biomass per recruit.
Conclusions: Biological reference points and virtual population analysis were prepared to plan appropriate managements for *Sardinella aurita* fisheries.

1. Introduction

Round sardinella [*Sardinella aurita* (*S. aurita*), Valenciennes[1]] is a species very common in the Eastern Mediterranean Sea coast as well along the African Atlantic coasts from West Sahara to Angola. In addition, this species occurs in the Black Sea and in Western Atlantic from Cap Cod to Argentina, but it is rare.

Sardine is the first in its important to the Mediterranean Sea coast of Egypt. The round sardinella *S. aurita* are commercially exploiting in several Mediterranean countries such as Egypt, Algeria and Tunisia. In spite of the round sardinella is the most important, about 70% of total catch, in Mediterranean Sea coast of Sinai fishery, there are little information on fishery management of this species[2].

In view of the importance of the knowledge on species individual growth, it leads to determination of other parameters of its stock and eventually to a more precise resource developing. Author has thought it purposeful to conduct a study results of which might aid in a final formulation of growth characteristics, population dynamics, stock assessment and fisheries management of round sardinella belonging to the stock in question.

2. Materials and methods

From June 2012 until April 2013, a total of 1 393 specimens of *S. aurita* (total length, 7.6 to 19.8 cm; total weight, 3 to 66 g) were collected from mixed commercial catch by Purse-seine (Shensholla) gear about 90%, and by trammel net gear about 10% from El-Arish Marin Seaport.

Several scales (5–6) were removed from the below of pectoral fin, then they were washed and stored in dry in labeled envelopes individually. In the laboratory, scales were washed with sodium hydrochloride (5%) and cleaned with pure water and mounted dry between two glass slides, then examined under a microscope (5×) to determine the age. Also, the scale was measured for the total scale radius and the distance from the focus to each annulus using an eye piece micrometer.

Total length was measured to the nearest mm and total weight was recorded to the nearest one gram. Back-calculation lengths were done from scale measurements by using, equation: Ln = (Sn/

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The journal implements double-blind peer review practiced by specially invited international editorial board members.

S) L, where, Ln is the length of fish at age "n", Sn is a magnified scale radius to "n" annulus[3]. S is a magnified total scale radius. L is a fish length at capture.

Constants of von Bertalanffy's[4], growth equation were calculated by applying plot[5].

Instantaneous total mortality coefficient "Z" was estimated by Jackson's method[6]. Instantaneous natural mortality coefficient "M" was estimated by the equation of Chen and Watanabe[7]. The fishing mortality coefficient "F" was estimated by subtracting the natural mortality coefficient from the total mortality coefficient.

The exploitation rate "E" was estimated by the formula suggested by Gulland[8]. Estimation of survival rates "S" as the number of fish alive after a specified time interval was divided by the initial number, and was usually done according to Ricker's equation on a yearly basis[9].

Length and age at the first capture (L_c and t_c), also length and age at the first recruit (L_r and t_r) were determined by the equations of Beverton and Holt[10,11].

The average length at the first maturity (L_m) was calculated from an empirical relationship between length at the first maturity and asymptotic length L[12].

The yield per recruit (Y/R) was estimated by Gulland's model[13]. Beverton and Holt[11] reported the biomass per recruit (B/R) model was obtained by the equation: B/R = (Y/R)/F, where "F" is the fishing mortality.

Biological reference points "R/B", "F_{max}" and "$F_{0.1}$" were obtained according to Cadima[14]. The effects of age and length at the first capture on yield per recruit at the present value of fishing mortality and at different fishing mortality values were estimated, the ratio $F_{cur}/F_{0.1}$ was calculated to indicate the stock status.

Pope's[15] virtual population analysis has become one of the most commonly used age- and time-dependent fish population models in fisheries science[16] to analyze the historical data for estimation of population parameters of *S. aurita* in the coast of North Sinai.

3. Results

In spite of the wide distribution and importcane of *S. aurita* there are just few publications existing on their fisheries managements. Fisheries management needed estimates of harvest level that provided maximum yield on a long term basis.

3.1. Growth

3.1.1. Growth in length

The back-calculation length of *S. aurita* was determined as 8.16, 11.58, 14.36, and 16.73 cm for ages 1, 2, 3 and 4 years respectively. The annual increment in lengths was 8.16, 3.42, 2.78 and 2.38 cm for ages 1, 2, 3 and 4 years respectively. It was clear that the highest increment in length for *S. aurita* occurred at the first year of life (8.16 cm) and then declined rapidly, reaching its minimal value during the fourth year of life (Table 1 and Figure 1).

Table 1

Back-calculated length of *S. aurita* from the coast of North Sinai.

Age (year)	Number of fish	Observation length	Back-calculated total length (cm)			
			1	2	3	4
1	135	11.98	8.16			
2	826	14.13	6.43	11.58		
3	361	16.04	6.84	12.31	14.36	
4	29	18.14	6.56	11.81	13.78	16.73
Mean ± SD			7.00 ± 0.79	11.90 ± 0.37	14.07 ± 0.41	16.73 ± 0.00
Increment			8.16	3.42	2.78	2.38
% Increment			48.76	20.44	16.60	14.20

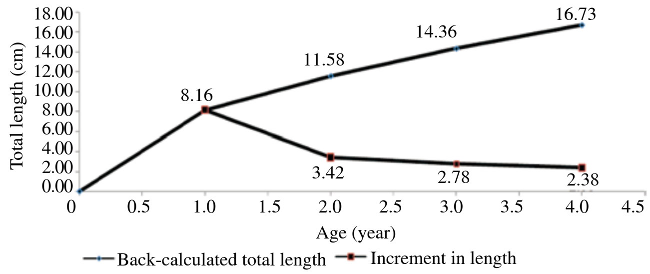

Figure 1. Increment in length of *S. aurita* from the coast of North Sinai.

3.1.2. Growth in weight

The back-calculation weight of *S. aurita* was determined as 4.74, 12.84, 23.69, and 36.65 g for ages 1, 2, 3 and 4 years respectively. The annual increment in weights was 4.74, 8.10, 10.85 and 12.96 g for ages 1, 2, 3 and 4 years respectively. It was clear that the highest increment in weight for *S. aurita* occurred at the fourth year of life (12.96 g), where it rapidly increased in weight from first, second, third and fourth year of life (Table 2 and Figure 2).

Table 2

Back-calculated weight of *S. aurita* from the coast of North Sinai.

Age (year)	Number of fish	Observation weight	Back-calculated total weight (g)			
			1	2	3	4
1	135	13.74	4.74			
2	826	22.89	2.41	12.84		
3	361	33.12	2.86	15.27	23.69	
4	29	48.14	2.55	13.59	21.08	36.65
Mean ± SD			3.14 ± 1.08	13.90 ± 1.24	22.39 ± 1.84	36.65 ± 0.00
Increment			4.74	8.10	10.85	12.96
% Increment			12.93	22.11	29.60	35.36

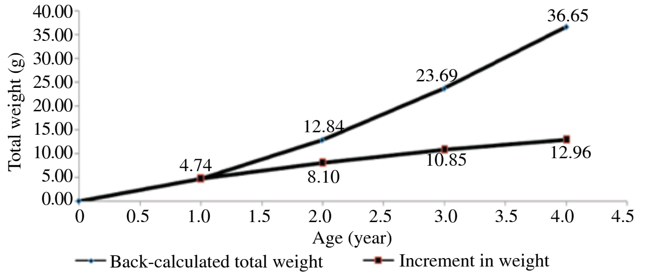

Figure 2. Increment in weight of *S. aurita* from the coast of North Sinai.

3.1.3. Theoretical growth in length and weight

Theoretical growth in length and weight of *S. aurita* in the Eastern Mediterranean Sea was solved by von Bertalanffy[4], growth equation for length and weight by fitting[5] plot, and found as follows:

For length $Lt = 28.36\ (1 - e^{-0.184\ (t + 0.8437)})$

For weight $Wt = 186.8\ (1 - e^{-0.184\ (t + 0.8437)})^{2.848}$

Constants of von Bertalanffy's growth equation (L_∞, k, t_o and W_∞) by using[5] plot in the coast of North Sinai was 28.36 cm, 0.184 per year, –0.8437 per year and 186.8 g, respectively.

3.2. Population dynamics

Total mortality coefficient (Z), defined as the total loss by natural and fishing death of individuals was (Z = 0.88 per year). Instantaneous natural mortality as obtained by the equations of Chen and Watanabe[7] was (M = 0.45 per year), versus fishing mortality (F = 0.43 per year) was observed for *S. aurita*. The current established exploitation rate was 0.49 (E = 49%), where it reaches the optimum exploitation rate at E = 0.5, suggested by Gulland[8]. Survival rate (S) for *S. aurita* in the coast of North Sinai was (S = 0.42 per year).

3.3. Management

3.3.1. Length and age at first capture, recruit and maturity

Length at the first capture were the length at which the probability of capture was 50%. Length at the first capture (L_c) of *S. aurita* was 11.17 cm corresponding age (t_c) 1.88 years.

Length and age at first recruit (L_r and t_r) for *S. aurita* were 9.65 cm, 1.42 years respectively, these values showed that *S. aurita* in the coast of North Sinai was recruited at an age more than one year.

Length and age at the first maturity (L_m and t_m) for *S. aurita* was 11.71 cm, corresponding age t_m 2.05 years.

3.3.2. Yield per recruit (Y/R) and biomass per recruit (B/R)

The yield per recruit (Y/R) and biomass per recruit (B/R) of *S. aurita* in the coast of North Sinai were found to be 6.914 g and 16.151 g respectively at the actual fishing mortality 0.43 per year.

For different values of fishing mortality coefficient effecting on yield and biomass per recruit results found that the maximum value of yield per recruit was 7.451 g at the actual fishing mortality per year. This means that the present level of fishing mortality coefficient was less than the fishing mortality coefficient produced the maximum yield per recruit. Biomass per recruit was decreased with the increasing of fishing mortality where it reached the maximum (49.82 g) at F = 0 (Table 3).

Table 3

Yield per recruit and biomass per recruit of *S. aurita* from the coast of North Sinai.

Fishing mortality (%)	Yield per recruit (g)	Biomass per recruit (g)
0.00	0.000	49.823
0.10	3.526	35.265
0.15	4.560	30.400
0.20	5.309	26.547
0.25	5.861	23.442
0.30	6.270	20.901
0.35	6.577	18.792
0.40	6.808	17.021
0.428	6.912	16.151
0.50	7.116	14.231
1.00	7.451	7.451
1.50	7.341	4.894
2.00	7.204	3.602
2.50	7.089	2.836

3.3.3. Length at first capture (Lc) against (Y/R)

Table 4 represents the affect of different values of age at the first capture on yield per recruit, according to the actual value of fishing mortality.

Table 4

Effect of length at first capture on Y/R of *S. aurita* from the coast of North Sinai.

L_c (cm)	Yield per recruit (g)
0.00	3.401
1.00	3.697
2.00	4.027
4.00	4.770
6.00	5.554
8.00	6.260
10.00	6.762
11.17	6.914
13.00	6.891
15.00	6.466

From this table it is notice that, going from the low value of L_c (1 cm) to its actual value, a rapid rise in the value of Y/R was occurred. Hence, the actual value of L_c (11.17) realized the maximum value of Y/R= 6.914, where the yield per recruit was decreased by the increase of length at the first capture.

3.3.4. Biological reference points (F_{max} and $F_{0.1}$)

According to Cadima[14] F_{max} is the point of the curve of yield per recruit (Y/R) against fishing mortality (F), where Y/R is the maximum. While, $F_{0.1}$ is the value of F, where Y/R is equal to 10 percent of Y/R maximum. In the present study, we found that F_{max} was 1.0 per year with maximum yield per recruit Y/R_{max} = 7.451 g, and biomass per recruit B_{max} = 7.45 g (with percentage 14.96% from the virgin stock biomass). The target reference point $F_{0.1}$ of *S. aurita* was found to be $F_{0.1}$ = 0.35 per year with yield per recruit $Y/R_{0.1}$ = 6.577 g and biomass per recruit $B_{0.1}$ = 18.792 g (with percentage 37.72% from the virgin stock biomass). Which it is less than the actual value of the fishing mortality F_{pr} = 0.428 per year (Figure 3).

3.3.5. Virtual population analysis

The cohort model was based on the principle that if we know how many fish died from natural causes and we know how many were caught, we can reconstruct the history of the cohort (Table 5).

Table 5

Population size, survivors, natural mortality, cohort catches and fishing mortality of *S. aurita* from the coast of North Sinai.

Age groups	Population number	Survivors	Natural mortality	Catches number	Fishing mortality
0	267 921 395	131 662 802	128 761 716	7 496 878	0.2606
1	131 662 802	62 190 268	61 849 535	7 622 999	0.3002
2	62 190 268	13 814 549	20 374 532	28 001 187	1.0546
3	13 814 549	1 641 145	3 714 912	8 458 492	1.6805
4	1 641 145	0	1 173 633	467 512	0.4280

At the beginning of cohort at age zero, the population have had the maximum number of individuals, therefore it started to collapse by progress in time and age to reach to the smallest size in 4th age group. Moreover, the survivors from cohort individuals at one year to the next year were decreased by the increase of natural and fishing mortality. Natural mortality (which causes by predation, diseases and pollution) starts at high level in the youngest age groups then decreased to minimum at oldest age groups. In the begging of fishes life fishing

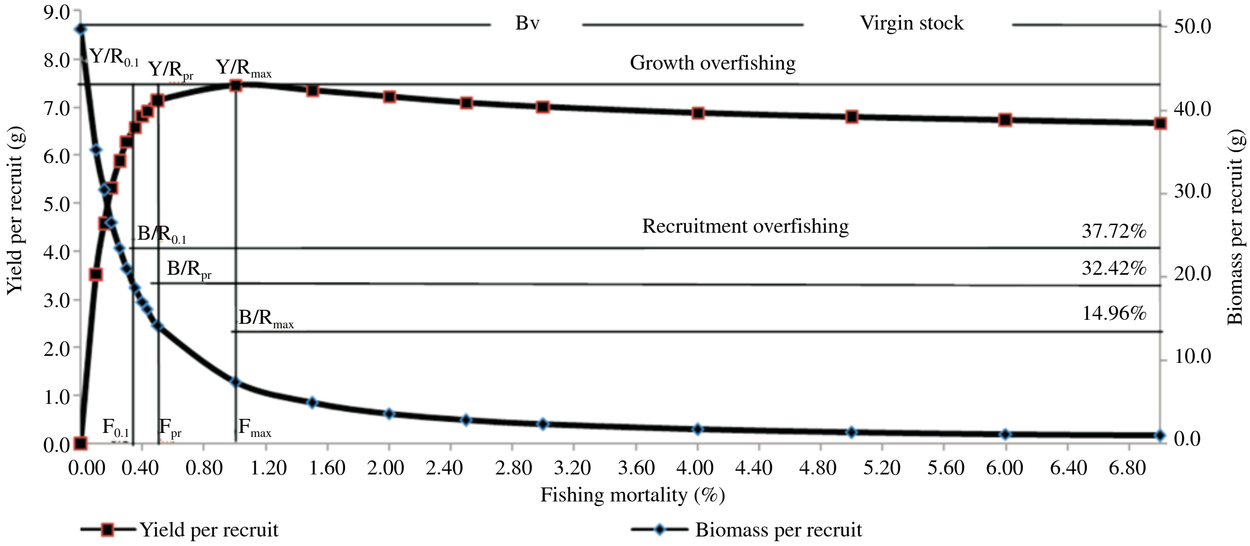

Figure 3. Yield per recruit according to the different values of fishing mortality ($F_{0.1}$, F_{pr} and F_{max}) of *S. aurita* from the coast of North Sinai.

mortality still at the minimum value (0.2606 per year) at age group zero, then it increases by the increase of age to reach its maximum value at age group 3rd (1.6805 per year), then it decreases in oldest age group.

4. Discussion

The concepts of fishery management are to provide advice on the optimum exploitation of aquatic living resources such as fish. Fisheries management needs the estimates of harvest level that provided maximum yield on a long term basis.

The average back-calculation length at the end of each year of the present study is less than the study done by EL-Maghraby *et al.*[17], Faltas[18], EL-Aiatt[19] and Salem *et al.*[20], whereas, agree with el Hakim *et al.*[21].

The average back-calculation weight at the end of each year of the present study is less than the study done by EL-Maghraby *et al.*[17]; Soliman *et al.*[22] and EL-Aiatt[19], while, agree with el Hakim *et al.*[21].

Constants of von Bertalanffy's growth equation (L_∞, k, t_o and W_∞) for *S. aurita* in the coast North Sinai were found in agreement with L_∞ between present work and many authors along Egyptian Mediterranean Sea coast, where, it agrees with EL-Maghraby *et al.*[17] and Abdall and EL-Hawee[23] in Alexandria; EL-Aiatt[19] and Salem *et al.*[20] in North Sinai. That means, *S. aurita* growth to its asymptotic length at the same rate along Egyptian coast.

In coast of Senegal, Krzeptowski[24] found that constants of von Bertalanffy's growth equation L_∞, k, t_o and W_∞ were 33.1 cm, 0.2832 per year, –0.989 per year and 620 g, respectively. This result is clearly different because of the abundance of nutrition along the West African coast at the Atlantic Ocean.

Total mortality coefficient (Z) for *S. aurita* individuals was 0.88 per year, this value is in agree with el Hakim *et al.*[21]. Wihle, different results obtained by Hashem and Faltas[25] estimated the total mortality for *S. aurita* in Alexandria is 1.377 per year[19]. Z = 1.262 per year and 1.519 per year in season 2000 and 2001 respectively.

Natural mortality was 0.45 per year versus fish mortality 0.43 per year observed for indicating the balanced position of the stock.

The same species may have different natural mortality rates in different areas depending on the density of predators and competitor's whose abundance is influenced by fish activities[26]. Gulland[8] suggested that fishing mortality should be about equal to natural mortality, resulting in an exploitation rate of 0.5 per year. However, exploitation rates should be very conservative for relatively long lived species[27]. In this work, the current established exploitation rate was 0.49. The current exploitation rate is not fully exploited stock (equal to 50%) according to Gulland[8].

The model of Gulland[13] can be used to forecast the effects of development and management measures, such as increase or reduction of fishing fleets, changes in minimum mesh sizes, *etc*. Therefore, this model forms a direct link between fish stock assessment and fisheries resources management[28].

In the present study we found yield per recruit of *S. aurita* was less than the maximum yield per recruit as we can be obtained, this means that the present level of fishing mortality coefficient is lower than the fishing mortality coefficient which produces the maximum yield per recruit, but that isn't attain any obvious economic proceeds.

Calculating biological reference points (F_{max} and $F_{0.1}$) provide useful and good background for the fisheries status of *S. aurita* in East Mediterranean Sea, where it more than the target reference point ($F_{0.1}$) but certainly it did not reach the overexploited phase (higher than F_{max}). In addition, it must reduce fishing level to reach the target reference point $F_{0.1}$ to prevent reaching the overexploited stock and overfishing pressure of marine resources.

Although many sophisticated stock assessment methods have been developed[29], a relatively simple method, virtual population analysis (VPA), is still commonly used for assessing freshwater and marine fisheries resources because of its moderate data requirement and simple algorithm [30-33]. The corresponding optimum catches of *S. aurita* individuals from the cost of North Sinai by gears are still near to appropriate level but it appears that there are a high pressure of fishing level on 2nd and 3rd age groups.

From previous results we can deduct that *S. aurita* fisheries in East Mediterranean Sea fisheries are still receive equilibrium fishing pressure, but we also need to reduce fishing intensity to get the optimum circumstances, by finding other management solutions as well as organizing the fishing days and gears at sea.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgments

This research are supported by General Authority for Fish Resources Development (GAFRD), Egypt.

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