Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(3): 45 – 57 (2022)
www.ejabf.journals.ekb.eg

Growth, mortality and exploitation status of the narrow-barred Spanish mackerel *Scomberomorus commerson* in Saudi Arabian Gulf waters

Yousof Naser Alrashada

Animal Production and Aquaculture Departm ent, College of Agricultural and Food Science, King Faisal University, P.O. Box 420 Hofuf 31982 Al-Hasa, Saudi Arabia.
yalrashada@kfu.edu.sa

ARTICLE INFO

Article History:
Received: Oct. 20, 2021
Accepted: Feb. 19, 2022
Online: May 5, 2022

Keywords:
Spanish mackerel,
exploitation rate ,
Growth,
Mortality,
Exploitation

ABSTRACT

Length and weight data of 5331 individuals' Spanish mackerel were collected belonging to the landing site Jubail port of Saudi waters, west of the Arabian Gulf from October 2013 to September 2017 to estimate growth, mortality parameters, and exploitation rate using FiSAT program. According to the findings, the mean Von Bertalanffy growth characteristics were K = 0.24, L_∞ =156 cm, t_0 = -0.352 and ǿ = 3.76. Total mortality (Z), natural mortality (M), and fishing mortality (F) had respective means of 1.40, 0.43, and 0.97. The mean exploitation rate was found to be 0.69, which is higher than the 0.5 optimum value for sustainable fisheries. Mean longevity (T_{max}) was determined using the formula 3/K = 12 years. F_{opt} = 0.215 and F_{limit} = 0.286 were the mean target and limit biological reference values. Mean sizes at capture were 91.28 cm, 101.3 cm, and 111.32 cm, respectively, with probabilities of 0.25 (L25), 0.5 (L50), and 0.75 (L75). The present investigation indicated that the *S. commerson* is overexploited in this area, necessitating an immediate reduction in fishing pressure in order to achieve a durable fishery. In conclusion, for such economically significant species, more extensive research is recommended.

INTRODUCTION

The narrow-barred Spanish mackerel, *Scomberomorus commerson* often referred to as the kingfish, is a big carnivorous fish belonging to the family *Scombridae* (Mackerels, tunas, bonitos) subfamily: *Scombrinae* **(Randall, 1995)**. Small fish such as anchovies, clupeids, and carangids make up the majority of the diet for *S. commerson*, but squids and shrimp are also eaten **(Blaber *et al.*, 1990)**. *S. commerson* may be found along the coasts of Southeast Asia, Africa's east coast, the Arabian Gulf, the northern Indian Ocean's coast, and the southwest Pacific Ocean, where it lives in shallow coastal waters less than 100 meters deep and frequently interacts with reefs and shoals. *S. commerson* is made up mostly of tiny schools that migrate great distances, however, there have been reports of permanent resident populations as well **(Niamaimandi *et al.*, 2015)**. Spanish mackerel is abundant during September to May in the northern Arabian Gulf, where it is caught with 9 and 14 cm mesh gillnets and trolling gear while it is mostly caught in the southern Arabian Gulf with encircling gillnets and trolling lines **(Grandcourt *et al.*, 2005)**.

Kingfish locally known as "Kanaad", is the most popular and high consumption fish in Saudi Arabia due to its delicious meat, it fetches up to 80 SR. (3.77 SR= 1US $) per kg and it is becoming an essential target for Saudi fishermen. Kingfish is also imported from Gulf Cooperation Council countries **(Khan *et al.*, 2003; Motlagh and Shojaei, 2009; Roa-Ureta *et al.*, 2019)**. The total catch of kingfish in Saudi Arabia was 7,119 tons, 5075 tons from the Arabian Gulf, while the Red Sea reached 2,044 tons **(FishStatistics, 2014)**. *S. commerson* landings have dropped dramatically in the last decade, worsened by a lack of controls, raising worries about the fishery's sustainability **(Al-Hosni and Siddeek, 1999)**. In general, Spanish mackerel is classified as a threatened species **(IUCN, 2016; Eighani *et al.*, 2020)**.

Fisheries science has several goals, one of which is to inform managers on the state of commercially exploited fish stocks **(Barnett *et al.*, 2019; Hilborn *et al.*, 2020)**. Stock evaluation is crucial in the decision-making process for long-term fisheries management **(Benson and Stephenson, 2018)**. It is a method of gathering and evaluating demographic data about a fish population **(Punt, 2019)**. The method includes the application of mathematical and statistical models to estimate the historical development of one or more stocks in order to make quantitative predictions about their future behavior in order to improve fisheries resource management, maintain industry profitability and stability, and reduce bycatch and overfishing risks (**Punt, 2019; Privitera-Johnson and Punt, 2020).**

Therefore, the aim of the current investigation was to estimate the basic growth characteristics of narrow-barred Spanish mackerel, *Scomberomorus commerson* in Saudi Arabian Gulf waters and to give information on the level of exploitation, based on mortality estimates. The findings will aid in the evaluation, preservation, and management of *S. commerson* in the Arabian Gulf in the future.

MATERIALS AND METHODS

Data collection

The data set used in this study was composed of statistics landing annual catch data for Spanish mackerel (Fig. 1) were randomly obtained from the Fisheries Statistics, Fish Welfare Research Center in Al-Qatif, Saudi Ministry of Environment, Water and Agriculture during the period from 2013 to 2017 (Ministry of Environment, Water and Agriculture). The total of 5331 individuals belonging to the landing site Jubail port of Saudi waters, west of the Arabian Gulf (27°00'45.4"N and 49°39'29.2"E) (Fig. 2). The fork length and weight of a fish were measured to the closest centimeter and gram, respectively. The area depth under the sea surface was between 15-40 m. Commercial fishing vessels used 14 cm mesh gillnets, hooks, and lines to catch the kingfish.

Figure 1. The narrow-barred Spanish mackerel *Scomberomorus commerson*

Figure 1. Jubail landing site where kingfish were sampled.

Growth characteristics

Model progression analysis using the software ELEFAN 1 inside the FiSAT program was used to compute growth parameters K (growth coefficient) and L_∞

(asymptotic length) using the von Bertalanffy growth function (VBGF) **(Gayanilo *et al*., 1995)**. The assumption was that kingfish was a one stock.

$$\mathbf{L_t = L_\infty [1 - e^{-K (t-t_0)}]}$$

Where: L_t is the length of the fish at time t, L_∞ the asymptotic length, K growth coefficient and t_0 theoretical age at length equals to zero. The value of t_0 was calculated using empirical equation of **(Pauly, 1983)** as follows:

$$\mathbf{Log (-t_0) = -0.3922 - 0.2752 \, Log \, L_\infty - 1.038 \, Log \, K}$$

Growth performance index (φ') for *S. commerson* population in terms of length growth was calculated using the index of **(Pauly and Munro,1984)**.

$$\boldsymbol{\varphi' = Log \, K + 2 \, Log \, L_\infty.}$$

Predation, illness, age, and environmental conditions can all cause natural fish death. According to **Pauly (1983)**, there is a link between natural mortality and water temperatures. The natural mortality of fish will increase as the temperature of the water rises. Using Pauly empirical formulae, the yearly natural mortality rate (M) was calculated **(Pauly, 1980)**:

$$\mathbf{Log \, M = - 0.0066 - 0.279 \, log (L_\infty) + 0.6543 \, log (K) + 0.4634 \, log (T)}$$

where: M = Natural mortality, K = growth coefficient, L_∞ = Asymptotic length which are derived from the VBGF and T is the yearly mean water temperature which estimated at 26.4 °C. The total mortality rate (Z) was estimated from length based catch curves **(Beverton and Holt, 1957)**.

The fishing mortality rate (F) was computed as:

$$\mathbf{F = Z - M.}$$

The F_{opt} is a target of fishing mortality rate and F_{limit} is a biological reference points (BRPs) was computed by **Patterson (1992)** formula:

$$\mathbf{F_{opt} = 0.5M}$$

$$\mathbf{F_{limit} = 2/3M.}$$

The fraction of fishing mortality compared to overall mortality (E = F/Z) was used to calculate the exploitation rate (E). The probability of capture data was estimated using backwards extrapolation of the descending limb. Fitting the logistic function to probability of capture and size data yielded a selectivity curve, which was used to calculate sizes at capture at probabilities of 0.25 (L25), 0.5 (L50), and 0.75 (L75).

Longevity estimates (T_{max}) were computed by using the inverse of the VBGF **(King, 2013)**.

$$\mathbf{T_{max} = t_0 - (l/k) \, ln \, [1 - (L_i/L_\infty)]}$$

where: L_i is arbitrarily considered equal to 99% of the asymptotic length.

$$\mathbf{T_{max} = t_0 - (3/K).}$$

RESULTS AND DISCUSSION

The Spanish mackerel are caught in the Arabian Gulf, Gulf of Oman, and the Arabian Sea by littoral countries independently across their full distribution. **Hoolihan et al., (2006)** reported that the stock has an uniform geographical distribution in this region, which is compatible with a single intermingling genetic stock. Studies attempt to determine the fundamental development characteristics of the Spanish mackerel, *S. commerson*, in Saudi Arabian Gulf waters are very low.

1. Growth characteristics

In total, 5331 Spanish mackerel *S. commerson* were collected during the 2013 to 2017 period, and the size of these fish ranged from 43 in 2014 to 160 cm in 2016 FL (Fig.3). The mean frequency size varied from 79.34 cm FL (SD = 13.8) in 2017 to 89.61 cm FL (SD = 16.2) in 2016 (Fig. 3). The current study's findings differ from those of **Niamaimandi et al. (2015)**, who found that it ranged from 17 to 152 cm in a commercial catch in the northern Arabian Gulf, **Newman *et al.*, (2012)** , who found that it ranged from 6.2 to 178.0 cm in Western Australia, and **Grandcourt *et al*. (2005)**, who found that it ranged from 21.0 to 135.0 cm in the southern Arabian Gulf. These findings might be explained by the fact that small-sized fish were underrepresented in the whole sample due to the Adriatic Sea's minimum landing size of 18 cm TL **(Meneghesso *et al.*, 2013)**. According to the regulations of fishing in Saudi waters, the nets used have large. In addition, most of the catches for Spanish mackerel were carried out by line and hooks.

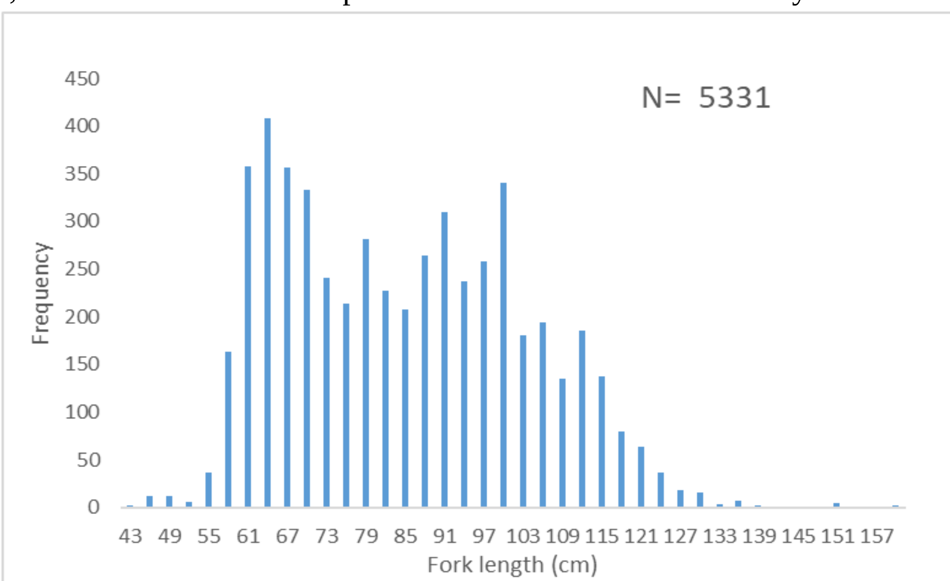

Figure 3. Annual fork length frequency of Spanish mackerel in Jubail, Arabian Gulf (2013–2017).

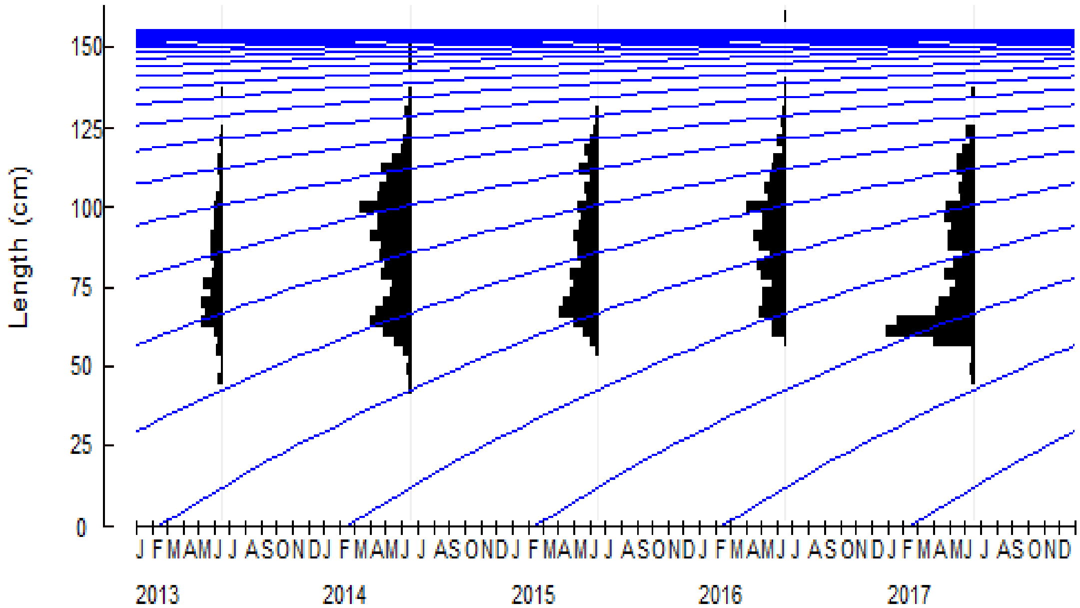

Figure 4. VBGF growth carves of *S. commerson* for the period, 2013-2017

Growth characteristics L_∞ and K were yield by VBGF in the ELEFAN1 program. L_∞ ranged between 124.2 (2016) to 157.7 (2014) cm FL with mean 156 cm FL while K varied between 0.24 to 0.29 year^{-1} with mean 0.24 (Fig. 4). The mean of growth performance index ǿ was 3.7665 (Table 1 and Fig. 5).

Table 1. Growth characteristics of samples caught from 2013 to 2017 form Jubail landing port.

Years	N	L_∞	K	t_0	ǿ
2013	485	145.5	0.29	-0.42939	3.7881
2014	1455	157.7	0.24	-0.35370	3.7759
2015	992	129.3	0.28	-0.39946	3.6704
2016	999	124.2	0.29	-0.41047	3.6506
2017	1400	145.8	0.26	-0.38041	3.7425
(2013-2017)	5331	156	0.24	-0.35241	3.7665

N= number of fish, L_∞ = the theoretical length at age infinity, K= growth coefficient, t_0 = theoretical age at length equals to zero, ǿ = growth performance index.

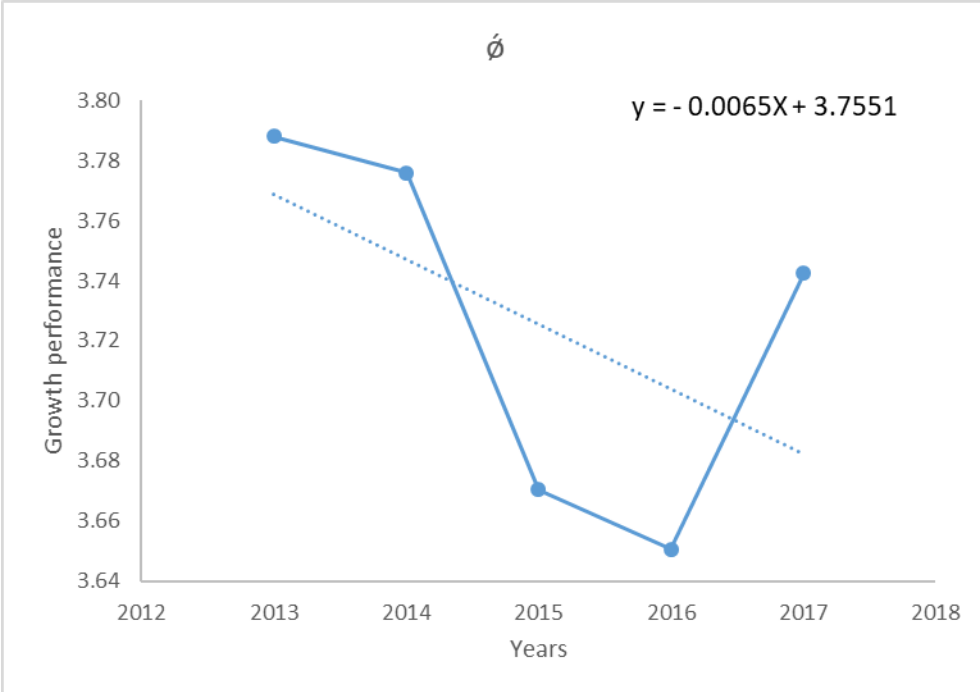

Figure 5. Growth performance index for Spanish mackerel during 2013-2017 period

Our results showed that the mean growth characteristics of Spanish mackerel (L_∞ = 156 cm, K = 0.24 year^{-1}, and t_0 = -0.35 year^{-1}) were lower than those obtained by **Kedidi *et al.*, (1994)** (L_∞ = 183.6 cm, and K = 0.26 year^{-1}) for kingfish in the Red Sea, Saudi Arabia. **AL-Hosni and Siddeek (1999)** measured L_∞, K, and t_0 in Omani waters and found that they were 173.6 cm, 0.28 year^{-1}, and -0.86 year^{-1}, respectively. **Taghavi Motlagh *et al*. (2008)** stated that the L_∞, K, and t_0 were 178 cm, 0.28 year-^{1}, and -0.36 year^{-1} in the Oman Sea, while Jayabalan *et al*. (2011) reported that the L_∞, K, and t_0 were 176cm, 0.4 year^{-1}, and -0.45 year^{-1} in the Gulf Cooperation Countries seas, respectively. These values for Spanish mackerel, on the other hand, were greater than those reported by **Niamaimandi *et al*. (2015)** in the northern Arabian Gulf, where L_∞ and K were 148 cm and 0.5 year^{-1}, respectively. The combined sexes in the United Arab Emirate were calculated to be K = 0.21 year^{-1} and L_∞ = 138.6 cm **(Grandcourt *et al*., 2005)**.

2. Mortality and exploitation rates

The mean of total mortality rate (Z) from 2013 to 2017 of *S. commerson* was calculated using Beverton-Holt method **Pauly (1980)**, which yielded Z of 1.40. The estimated value of K = 0.24, L_∞= 156 cm for *S. commerson* was used to calculate the mean natural mortality rate (M) using **Pauly's (1983)** empirical equation. In the Jubail, the average water temperature (T) was 26.4°C.

Table 2. Total mortality rate, natural mortality rate, fishing mortality rate, and exploitation rate of Spanish mackerel.

Years	Z	M	F	E
2013	1.22	0.51	0.72	0.59
2014	0.92	0.43	0.49	0.53
2015	0.62	0.50	0.12	0.19
2016	0.74	0.52	0.22	0.30
2017	0.82	0.46	0.33	0.41
(2013-2017)	1.40	0.43	0.97	0.69

Z= total mortality rate, M = natural mortality, F = fishing mortality, E = exploitation rate

The predicted Z of 1.40 and M of 0.43 for *S. commerson* were then obtained. The fishing mortality rate (F) is estimated as 0.97. The exploitation rate (E) was calculated to be 0.69 (Table 2 and Fig. 6).

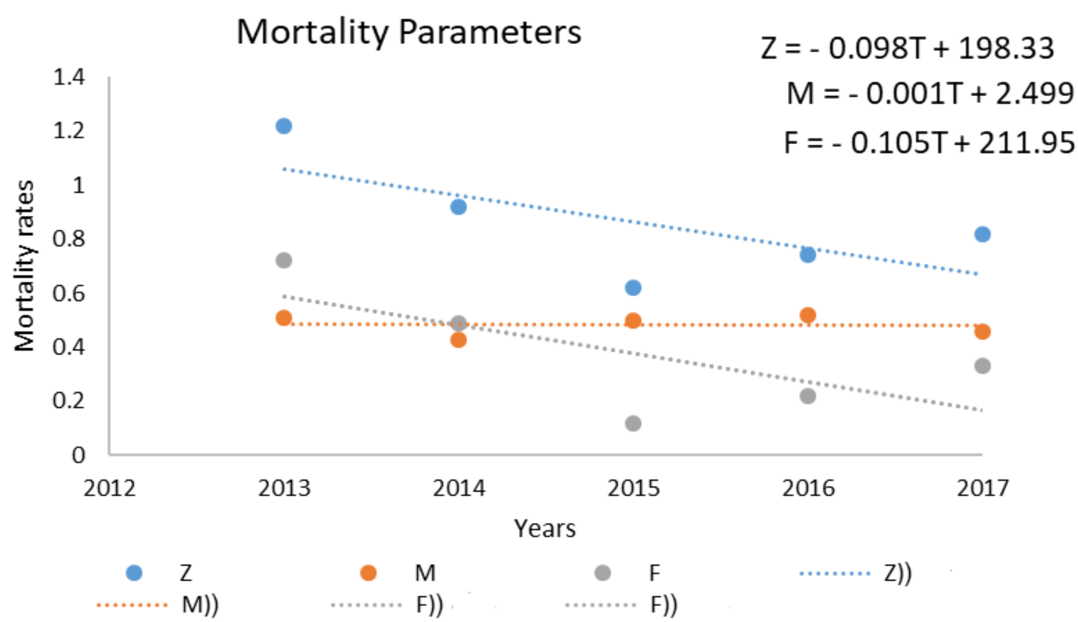

Figure 6. Trend of mortality parameters and exploitation rate of Spanish mackerel during 2013-2017.

These findings in agreement with those of **Shojaei *et al.*, (2007)**, who found Z=1.47, M=0.49 and F=0.98 in Iranian coastal waters. While the results were higher than those obtained by both **Niamaimandi *et al*., (2015)** in the northern Arabian Gulf where Z= 0.97 and **Taghavi *et al*. (2008)** in the GCC seas where Z= 0.95, M= 0.36, F= 0.59, and **Mcllwain *et al* (2005)** in the Oman where Z =1.321, M= 0.443, F=0.878. The mean fishing mortality rates for *S. commerson* were significantly higher than the mean rates of natural mortality. This revealed that, with the exception of 2015 and 2016, fishing activities were the primary cause of kingfish mortality in Jubail, west Arabian Gulf.

The mean exploitation rate of 0.69 suggested that the kingfish was being exploited at a greater rate than the optimal level (F_{opt} = 0.215). According to **Gulland (1983)**, the optimal rate of resource utilization is 0.5M. To ensure the long-term viability of the kingfish stock in this region, preventive management techniques such as limiting and regulating the number of fishing fleets targeting kingfish are required.

The growth characteristics acquired by ELEFAN 1 (L_∞ = 156 cm and K = 0.24 year$^-$1) were shown in a length-converted catch curve (Fig. 7) that allowed the immediate total mortality to be calculated.

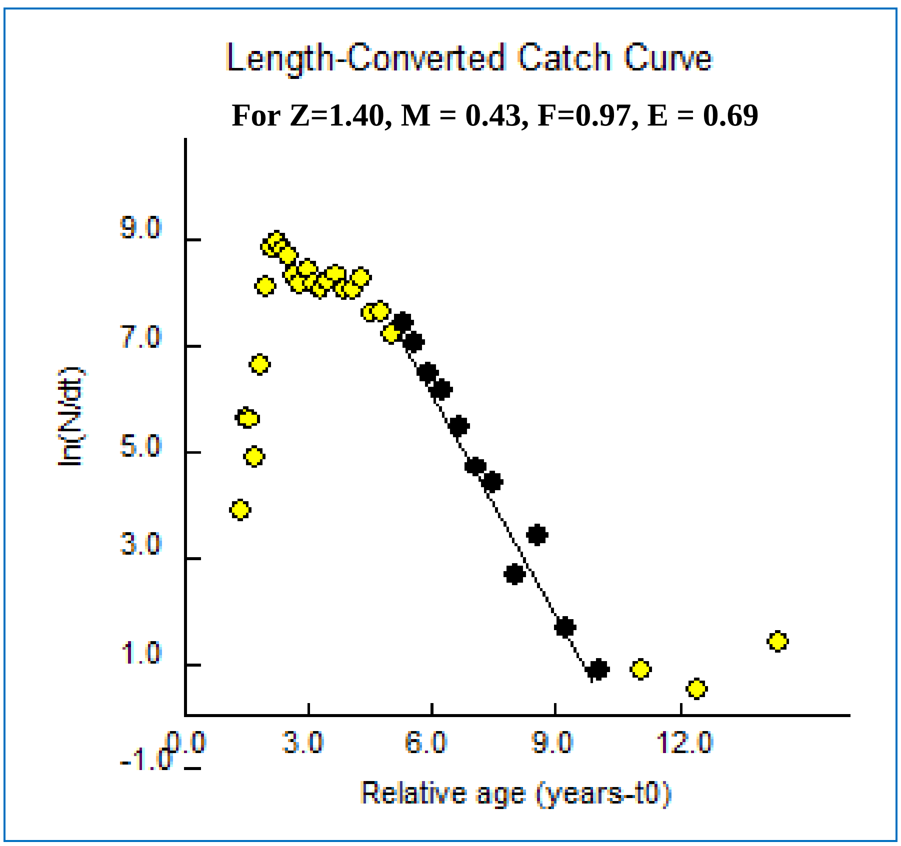

Figure 7. Catch curve analysis of *S. commerson* in Jubail, west Arabian Gulf (2013-2017). N – the number of fish in each age group (cohort); dt - the age difference between two age groups.

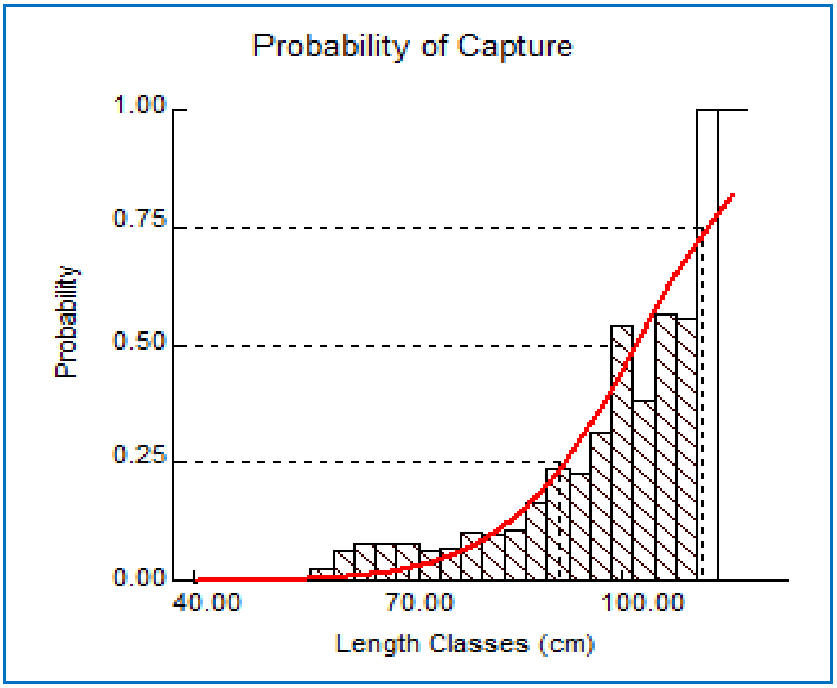

Figure 8. Calculated likelihood of capture by the length of Spanish mackerel taken by the fishery in Jubail, west Arabian Gulf (2013–2017).

The ratio of actual numbers captured by length class, calculated using ELEFAN II and mesh selectivity corrected for each length class. The mean values of L25%, L50% and L75% were 91.28, 101.3 and 111.32 cm FL, respectively (Fig. 8). The growth coefficient K affects how quickly the fish reach L_∞ **(Garcia *et al.*, 1989)**. The K value of Spanish mackerel in Saudi Arabian Gulf waters is 0.24 per year, which is considered low (< 0.5 per year), indicating that the fish achieves its L_∞ value slowly **(Grandcourt *et al.*, 2005; Darvhisi *et al.*, 2012; Newman *et al.*, 2012).**

CONCLUSION

One of the most significant pelagic fish species captured in Saudi Arabia is the Spanish mackerel. The current study found that the species is growing at a moderate rate and that the fishery is overexploited. The requirement to reduce fishing effort is critical for achieving a sustainable fishery.

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