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Research Article

Life history parameters and stock status of the yellowstrip barracuda *Sphyraena chrysotaenia* (family Sphyraenidae) in the Gulf of Aqaba, Egypt

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Abstract

Yellowstrip barracuda, *Sphyraena chrysotaenia* (Klunzinger, 1884) is exploited by gillnets along the Gulf of Aqaba coast, Red Sea, Egypt. Although barracuda species were caught in considerable amounts in the Gulf, there are no separate records for their catch. The population parameters of *S. chrysotaenia* were investigated in the Gulf of Aqaba, Egypt to cover the gap in the knowledge about the life history of the species in this area. A total of 590 individuals were examined by bi-monthly sampling from January 2021 to June 2023. The total length distribution of *S. chrysotaenia* ranged from 16.0 to 35.3 cm and the weight distribution from 25.0 to 240.0 g. Length- weight investigation showed that females were slightly heavier than males of the same size and both sexes showed negative allometric growth. The maximum ages resultant from otolith readings were six years for females and males. Growth parameters, L_∞, K and t_0 were estimated as 39.87 cm TL, 0.296/year and -0.52 year, respectively. Natural mortality of the stock was 0.64/year, and total mortality was 1.67/year, while fishing mortality was 1.03/year. Accordingly, the exploitation ratio was calculated as 0.62, indicating that the resource is currently under high fishing pressure, and any further increase in effort impact the fishery. E_{max} and $E_{0.5}$ were 1.0 and 0.41, respectively and therefore, it is recommended to decrease the fishing effort to attain $E_{0.5}$ or to keep it at its current level. To the best of our knowledge, this study is the first time to evaluate the age, growth and mortality rates of this species in the Gulf of Aqaba, and the findings of this study will be valuable for fishery managers and for sustainable exploitation.

Introduction

The family Sphyraenida, which is popularly called barracudas, has only one genus worldwide, *Sphyraena* with 29 species (Fishbase, 2024). Seven species are known to exist in the Gulf of Aqaba (Personal observation), of these, *Sphyraena chrysotaenia* (Klunzinqer, 1884), *S. jello* (Cuvier, 1829), *S. obtusata* (Cuvier, 1829), *S. barracuda* (Edwards, 1771), *S. putnamae* (Jordan and Seale, 1905), *S. flavicauda* (Rüppell, 1838) and *S. qenie* (Klunzinger, 1870) formed a fishery of considerable importance. *S. chrysotaenia* is widely distributed in the tropical waters of the Indian and the Pacific Oceans and prefers to be near shore in lagoons, bays and reefs and is known to move in shoals (Senou, 2001). Members of the family sphyraenidae are an important constituent of the Gulf of Aqaba, where they are caught in profitable quantities by lines, gill nets, and trammel nets.

Basically, fish stock assessment aims to provide advice about the optimum level of exploitation to fishery managers and it is an effective tool for managing the resources using the information on population features gained from age and growth studies (Sparre and Venema, 1998). Mortality rates are necessary in understanding the dynamics of any fish population and without knowledge of how fast individuals are removed from a population, it is impossible to model the population dynamics or estimate sustainable rates of exploitation. Though information on population dynamics exists for other barracuda species globally (Wadie and Rizkalla, 2001; Allam *et al.*, 2004; Apostolidis and Stergiou, 2014; Bourehail and Kara, 2021; Ghosh *et al.*, 2021; Erguden and Ozdemir, 2022; Ferri and Brzica, 2022), no information is available for *S. chrysotaenia* from the Gulf of Aqaba.

The Gulf of Aqaba is a warm, semi-enclosed, narrow, high-salinity and oligotrophic water body. The Gulf is of significant ecological value with unique ecosystems that host one of the most diverse coral communities in the world. However, these marine environments and biodiversity have been threatened by growing human activities. It is approximately 180 km long and 14-26 km wide, and represents a natural resource of major economic significance in terms of access to marine transportation routes, the development of tourism and other industries along its shores. Coral reef communities in the Gulf have a high diversity of marine taxa and provide habitat for endemic and rare marine species.

Consequently, the current study was undertaken to estimate the different population parameters and to explore the population dynamics for *S. chrysotaenia* exploited by gillnets from the Gulf of Aqaba. The obtained results will help in sustainable management policy for this commercially important species in the region.

Materials and methods

Biological samples from the fishery by gillnets of *S. chrysotaenia* at the Gulf of Aqaba were gathered during 2021-2023 at bi-monthly intervals from the local fishermen operating in the area between Taba and Dahab cities (Fig. 1). The local fishermen were interviewed to collect data about fishing activities and methods used.

The fishery in the Gulf of Aqaba is small-scale with boats that not exceed 12 m length with the bulk of 7-9 m length using gillnets and lines to catch fish. The fishing hours were about 12 hour/day starting with sunset and ending with sunrise with an average catch of 70 kg/boat/day. The data on the fish size (total length) was measured in centimeters using the wooden measuring board, while weight was recorded using a digital balance to the nearest 0.1 g. Sex was determined by macroscopic analysis of the gonads, and sagittal otolith pairs were removed, cleaned, and stored dry in labeled Eppendorf tubes for further investigation.

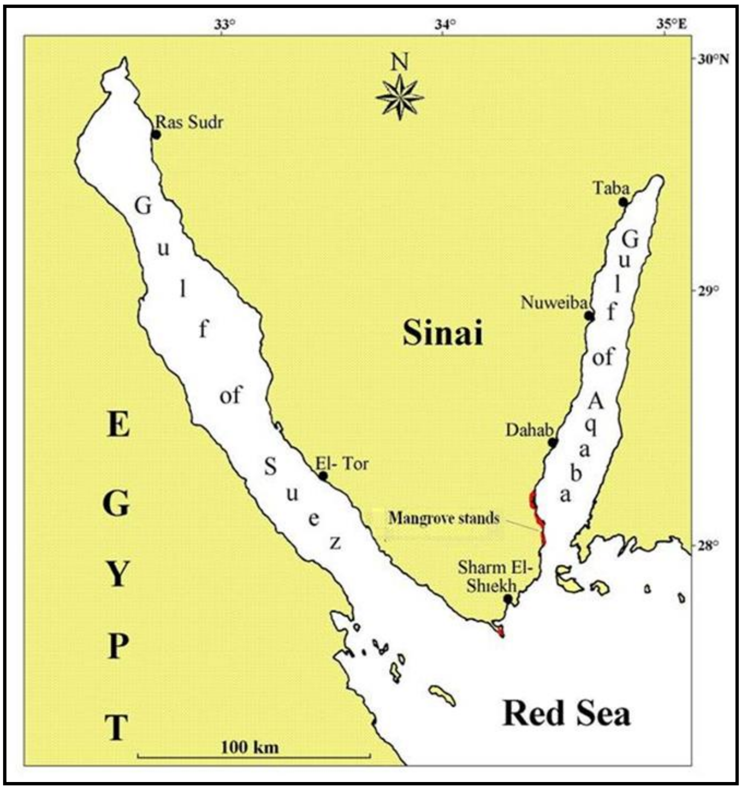

Figure 1: Map of the study area, Gulf of Aqaba, Red Sea, Egypt.

Length-weight relationship was estimated following power regression analysis $W=aL^b$ (Le Cren, 1951), whereas W designates the weight of species in g, L indicates total length in cm, a is condition factor and b is the slope.

Age and growth were investigated through otoliths' readings. Otoliths were photographed via an Olympus DP-25 digital camera attached to Olympus SZX16 stereo microscope. Age determination was validated through three readings by three different readers.

Von Bertalanffy (1938) growth equation (VBGF) $L_t=L\infty\ (1 - e^{(-k(t-t_0)})$ was applied to determine growth parameters where L_t is the predicted length (cm) in age t, $L\infty$ is the asymptomatic length, K is the growth capacity and t_0 is hypothetical age at which the fish length is equal to zero. While t_0 was expected by substituting $L\infty$ (in cm) and K ($year^{-1}$) in the following equation (Pauly, 1982):

$$log(-t_0) \approx -0.3922 - 0.2752 L\infty - 1.038\ logK$$

Performance index of growth (Ø') of *S. chrysotaenia* was calculated using the equation of Pauly and Munro (1984) as $Ø' = \log_{10} K + 2 \log_{10} L\infty$; that is present in the computer Package with VBGF parameters for growth.

The potential longevity (maximum life span) of *S. chrysotaenia* was determined based on the formula of Weatherly and Gill (1987) as: $t_{max} = t_o + 3/K$

Size at first maturity was determined by the maturation curve method. A logistic function relating the proportions of mature individuals to total length of the fish (Ghorbel *et al*, 2002) was used. This function of sigmoid shape is expressed as follows: $P=1/1+e^{-(b+aTL})$, where P is the proportion of mature individuals, TL is the total length in cm and a and b are constants. While the length at first capture was calculated by the probability of capture curve method (Pauly, 1984).

Total mortality, exploitation, and yield per recruit were estimated from monthly length frequency data of the species in the catch using ICLARM's FiSAT software (Gayanilo *et al.*, 1996). The total mortality coefficient (Z) was estimated from the catch curve (Pauly, 1983).

Natural mortality (M) was estimated as the geometric mean of three methods; the formula of Peterson and Wroblewski (1984) as $M_w = 1.92\ W^{-0.25}$, the empirical formula of Jensen (1996) as $M = 1.65/L_m$ and that of Gislason *et al.* (2010) as $M_L = 1.73\ L^{-1.61}\ L\infty^{1.44}\ K$.

Exploitation rate (E) was estimated from the equation, E = F/Z as in Beverton and Holt (1957) and Ricker (1975), where F is the fishing mortality (Z-M). Relative yield per recruit and optimum exploitation rate were computed as in Beverton and Holt (1966).

Length structured Virtual Population Analysis (VPA) was used to obtain fishing mortalities per length class. Optimal fishing length (L_{opt}), the length at which the unfished cohort provides the maximum biomass was estimated from length frequency using the equation proposed by Froese and Binohlan (2000).

Results

Size composition and length distribution

Of the 590 individuals of the *S. chrysotaenia* sampled, 317 (53.8%) were males, and 273 (46.2%) were females. All sizes with a minimum and maximum TL at 16.0 and 35.3 cm with a mean of 23.54±2.21were represented in the fishery. The average size showed no significant difference between sexes (male: 23.51±3.83; female: 23.56±3.96) (t-test: p=0.081). The highest numbers of frequencies were observed from 18 to 20 and from 25 to 29 cm length classes (Fig. 2).

Length-weight relationship LWR

A total of 590 length and weight measurements of *S. chrysotaenia* were gathered to estimate the length and weight ratio. The length size and weight range were between 16 to 35.3 cm (23.54±2.21) and 25 to 240 g (100.13±6.75), respectively. The resultant LWR equation was:

Males $W = 0.0152\ L^{2.706}$

Females $W = 0.0125\ L^{2.778}$

Combined sexes $W = 0.0135\ L^{2.749}$

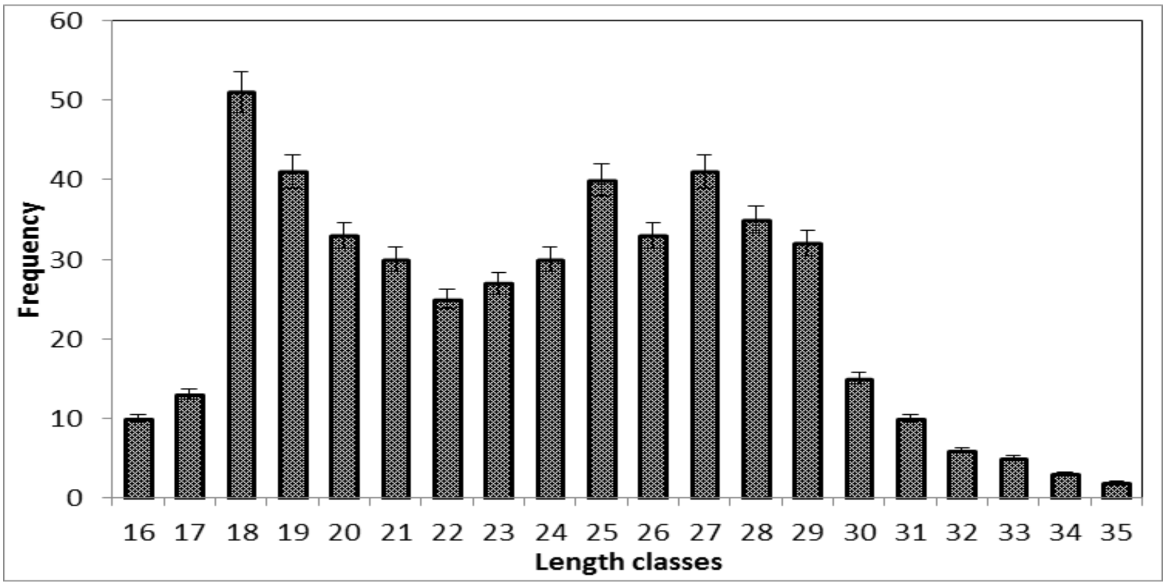

Figure 2: Length frequency distribution of *Sphyraena chrysotaenia* from the Gulf of Aqaba, Red Sea, Egypt.

Age and growth

In the Gulf of Aqaba, the longevity of *S. chrysotaenia* based on otoliths' readings (Fig. 3) reached six years and age groups I, II and III comprises 80.7% of sampled fish in (Fig. 4).

Figure 3: Otolith of *Sphyraena chrysotaenia* from the Gulf of Aqaba, Red Sea, Egypt (TL= 30.6 cm; Age: 4 years).

Population parameters and critical lengths

Von Bertalanffy growth parameters $L\infty$, K and t_o for sexes combined *S. chrysotaenia* were 39.87 cm TL, 0.296/year and -0.52 year, respectively, while the growth performance index was 2.67 and the potential longevity was 9.5 years. The size at first capture was estimated at 23.9 cm (Fig. 5), whereas the size at first maturity was 24.17 cm and the optimum length was 25.1 cm.

The annual total mortality of *S. chrysotaenia* was 1.67, annual natural mortality of the species was 0.64, and fishing mortality was 1.03, accordingly, the exploitation rate was 0.62.

Virtual population analysis and yield per recruit

According to virtual population analysis (VPA), the main loss in the stock less than 18 cm size was due to natural causes (Fig. 6). Fish were increasingly sensitive to the fishing gear after this size and mortality due to fishing increased.

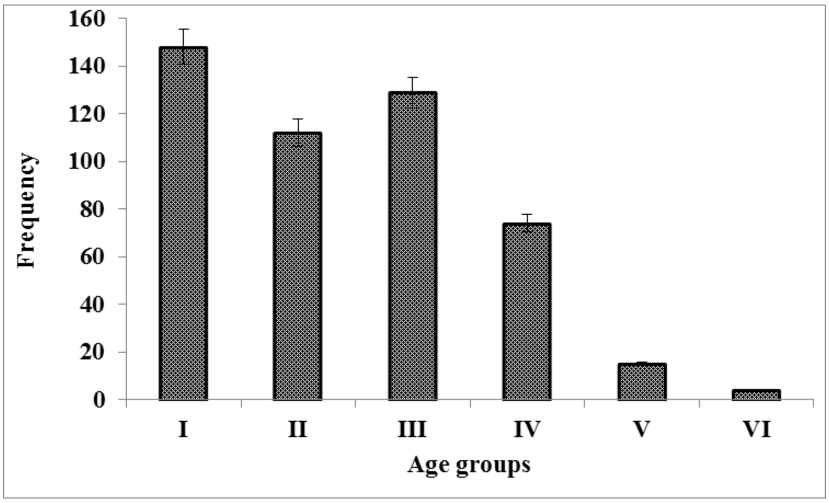

Figure 4: Age composition of *Sphyraena chrysotaenia* from the Gulf of Aqaba, Red Sea, Egypt.

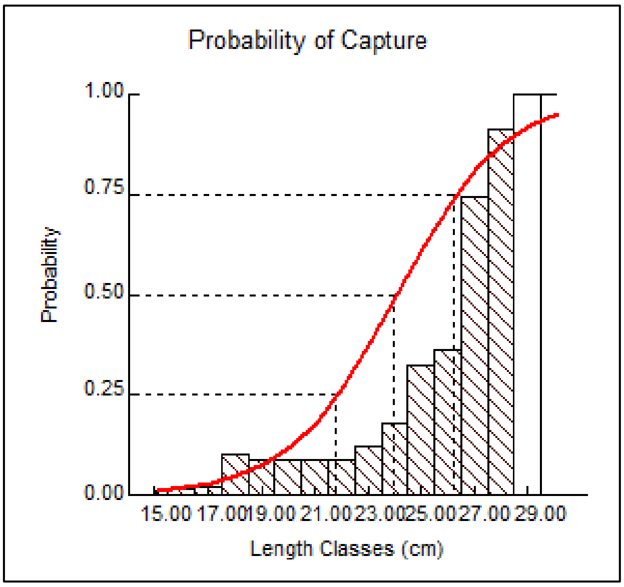

Figure 5: Probability of capture for *Sphyraena chrysotaenia* from the Gulf of Aqaba, Red Sea, Egypt.

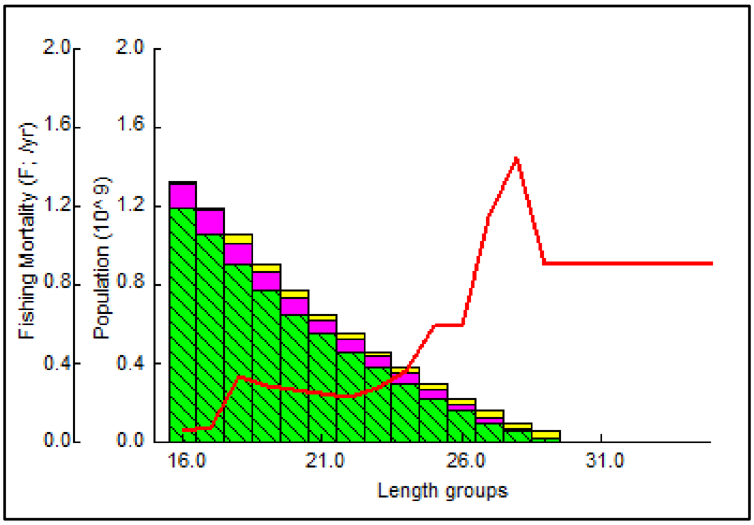

Figure 6: Length structured Virtual Population Analysis (VPA) of *Sphyraena chrysotaenia* from the Gulf of Aqaba, Red Sea, Egypt.

The most susceptible lengths for fishing gears were from 24 to 28 cm TL.

The results of relative yield per recruit analysis as a function of length at first capture (L_c) and M/K value (Fig. 7) revealed that, the maximum exploitation rate (E_{max}=0.99), the exploitation rate which maintains 50% of the stock biomass as spawning stock ($E_{0.5}$) was 0.41 which is lower than the current one (0.62).

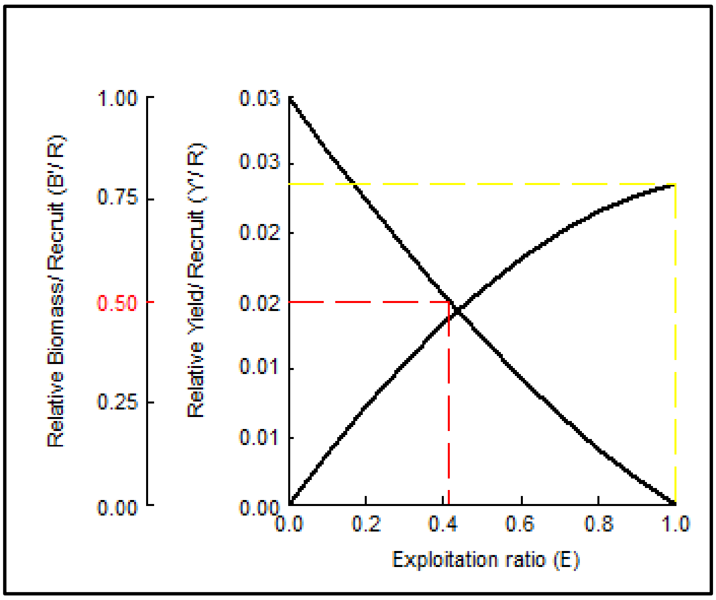

Figure 7: Relative yield per recruit and relative biomass per recruit of *Sphyraena chrysotaenia* from the Gulf of Aqaba, Red Sea, Egypt.

Discussion

Length frequency data have applied uses in fisheries science, where the analysis of length-frequency data can be used for studying age, growth, survival, and mortality rates. Of the 590 individuals of the *S. chrysotaenia* sampled, 317 (53.8%) were males, and 273 (46.2%) were females. The average size showed no significant difference between sexes (male: 23.51±3.83; female: 23.56±3.96) (t-test: p=0.081) and also there is no significant difference in size-frequency distribution between males and females (Kolmogorov-Smirnov two-sample test: d=0.113, p=0.781). From the length composition of sexes combined, it is obvious that all sizes were represented in the fishery with a minimum and maximum TL at 16.0 and 35.3 cm with a mean of 23.54±2.21. The recorded maximum length in this study (35.3 cm TL) was the highest reported length in the Egyptian waters (Allam *et al.*, 2004) and in the range given by Erguden and Ozdemir (2022) in Mediterranean waters of Turkey (34.5 cm TL).

The length-weight relationship is helpful in the investigation of metamorphosis, gonad maturity, the fish feeding rate and fish stock assessment (Le Cren, 1951), and it is the basic parameter in fish biology, fishery ecology and modeling aquatic ecosystems (Froese, 2006; Froese *et al.*, 2011; Mehanna and Farouk, 2021). A total of 590 length and weight measurements of *S. chrysotaenia* were gathered to estimate the length and weight ratio. The length size and weight range were between 16 to 35.3

cm (23.54±2.21) and 25 to 240 g (100.13±6.75), respectively. This relationship showed that females are slightly heavier than males of the same size and the analysis of covariance showed that males and females not differ significantly ($p>0.05$) in their length-weight relationship. The length-weight slops b for males was estimated at b=2.706 (R^2=0.944; 95% CI=2.679-2.733) and the slope b for females was estimated at 2.778 (R^2=0.961; 95% CI=2.736-2.820), while for both sexes combined it was calculated at 2.749 (R^2=0.968; 95% CI=2.720-2.778). A negative allometric growth (b<3) was recorded for this species, which means that it grows faster in length than in weight. The same type of growth was observed in the previous studies of Taskavak and Bilecenoglu (2001) from Turkey.

Age determination of fish is an important step for assessing the population's health (Berkeley *et al.*, 2004). Normally, an established, healthy population will show a sound balanced age structure (Brunel and Piet, 2013) with plentiful larger, older individuals. In the Gulf of Aqaba, *S. chrysotaenia* displayed an age distribution of 80.7% of fish in age groups I, II and III (Fig. 3). The back calculated lengths at age groups using the otolith readings (Fig. 4) were 18.21, 23.79, 27.81, 31.05, 33.17 and 34.95 cm TL at the end of the years from one to six year of life, respectively. *S. chrysotaenia* is considered small and short-lived barracuda and its longevity ranged from three to six years (Allam *et al.*, 2004; Rim *et al.*, 2009; Erguden and Ozdemir, 2022).

Growth parameters L_∞, K, and t_o for sexes combined were 39.87 cm TL, 0.296/year and -0.52 year, respectively. Growth performance index of *S. chrysotaenia* was calculated at 2.67 and the potential longevity was estimated as 9.5 years. The resultant growth parameters were differ from those reported in the previous studies (L_∞ was greater and K was smaller than those in the other studies) except the study of Erguden and Ozdemir (2021) in Turkey who gave the highest L_∞ and the smallest K reported for this species (L_∞=58.47 cm and K=0.091/year).

The size at first capture was estimated at 23.9 cm (Fig. 6), whereas the size at first maturity was 24.17 cm and the optimum length was 25.1 cm. The fish attained sexual maturity and spawned during the second year of life. However, fully matured fishes with ripe gonads were observed in the population from 20 cm TL. The L_c estimate designated that *S. chrysotaenia* was caught in smaller sizes compared to the size at first sexual maturity and optimum length for this stock in the Gulf of Suez. Based on the estimated L_c and L_m, the most caught *S. chrysotaenia* were at sizes not reached sexual maturity. Hence, there is a serious need to increase the mesh size of gillnets along the Gulf of Aqaba fishery at the present level of effort. This suggested the necessity of formulation and implementation of measures to increase the size at first capture and to reduce fishing pressure for sustaining stock and increasing yield.

Natural mortality (M) is one of the vital life history parameters in fisheries science (Beverton and Holt, 1957). Without an estimate of M, fishing mortality cannot be estimated from the age or size composition of catch, and the expected yield at any upcoming level of fishing cannot be predicted. Natural mortality of the species was 0.64, the total mortality was 1.67 and fishing mortality was 1.03. Accordingly, the exploitation rate was 0.62, which is higher than the optimum values of E (0.4-0.5), indicating a high fishing pressure.

According to virtual population analysis (VPA), natural mortality was responsible for deaths and losses of the population under 18 cm size, while fishing activities became the main reason for population losses after 18 cm size. It is obvious that the most susceptible lengths for fishing gears were from 24 to 28 cm TL.

The relative yield per recruit analysis as a function of length at first capture (L_c) and M/K value showed that the maximum exploitation rate (E_{max}=0.99) was greatly higher than the present level of exploitation rate (0.62), but any increase beyond this value will influence the fishery of the Gulf. Gulf of Aqaba fishery is a small-scale fishery with a multispecies nature, so any recommendations about increasing fishing effort should take into consideration this condition. At the same time and based on the yield per recruit analysis, little increase in yield will achieved with the increase in effort to unacceptable levels The exploitation rate which maintains 50% of the stock biomass as spawning stock ($E_{0.5}$) and considered as a target reference point was estimated at 0.41 which is lower than the current one.

Conclusion

Based on the estimated fishing mortality and exploitation ratio of *S. chrysotaenia* in the Gulf of Aqaba, it could be concluded that the fishing pressure on this species needs to be reduced or at least maintained at its current level. This will help to support the sustainability of this resource. Also, some management measures are required for the sustainable development of the Gulf fisheries, such as increasing the mesh sizes and monitoring of fishing effort. Also, the fishery statistics recording system needs urgent improvements to reflect the real catch and effort data.

Conflicts of interest

The authors declare that this research was conducted without any conflict of interest with any party.

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