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Population Parameters and Management of the Blackspot Snapper *Lutjanus ehrenbergii* (Family: Lutjanidae) from Two Different Areas of the Red Sea, Egypt

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ABSTRACT

The present study is a part of a wider research aimed to investigate fishery status and assessment of the blackspot snapper stock in the Gulf of Suez. A total of 356 and 345 specimens of *Lutjanus ehrenbergii* were consistently collected monthly for a year from the landing centers in Suez and Hurghada during the active fishing season from December 2022 to November 2023. After the length and weight measurements, each specimen was dissected to determine sex and gonadal development. Critical lengths L_r, L_c, and L_m for *L. ehrenbergii* were 14.3, 23.05, and 22.5cm from Suez, and 17.4, 23.6, and 21.9cm from Hurghada, respectively. These lengths were corresponding to ages of 0.63, 1.87, and 0.96 year for Suez, and 0.42, 2.19, and 0.91 year for Hurghada, respectively. The mean total, natural, and fishing mortality rates for *L. ehrenbergii* were 1.78, 0.54, and 1.24/year, in Suez, and 1.38, 0.54, and 0.84/year in Hurghada, respectively. The estimated exploitation rates for *L. ehrenbergii* landed in Suez and Hurghada were also 0.70 and 0.61/year, respectively, which were higher than the optimum level of exploitation. Y/R values were 51.3 and 49.5g/ recruit from the two landing sites. The present results revealed that the stock of the blackspot snapper in the Gulf of Suez is overexploited which presses for immediate measures to promote fishery health by lessening the fishing pressure in order to protect the stock from depletion.

INTRODUCTION

Egypt boasts a diverse array of water bodies, including the Red Sea, which is often regarded as a treasure trove of marine life. The Red Sea extends into the gulfs of Suez and Aqaba, with the Gulf of Suez (Fig. 1) being the most significant part of the Egyptian Red Sea fisheries. One of the key species caught by local artisanal fishers in the Gulf of Suez and the Red Sea is the blackspot snapper, a notable member of the Lutjanidae family.

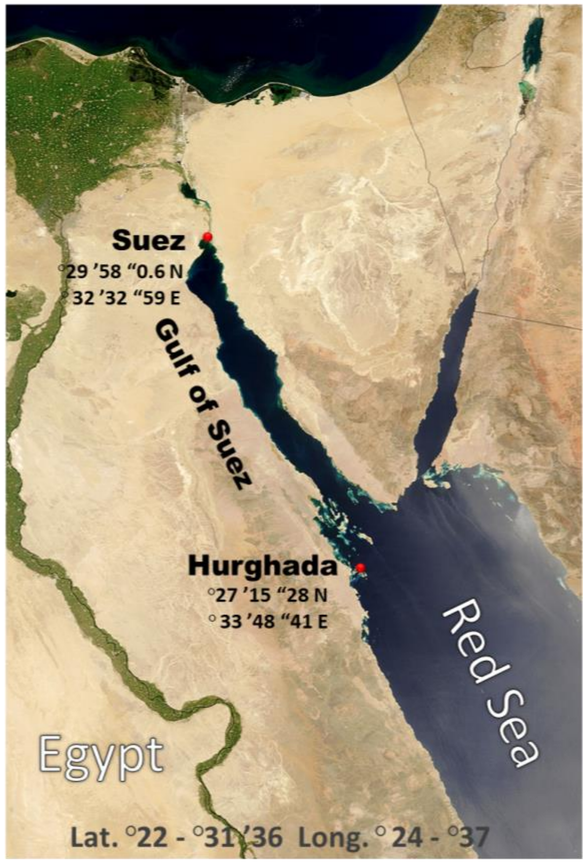


Fig. 1. The Gulf of Suez and Red Sea, Egypt

The blackspot snapper *Lutjanus ehrenbergii*, first described by Peters in 1869, is associated to the functional guild of invertivorous and even piscivorous fish **(Feary *et al.*, 2010)**. Many *Lutjanus* species have a relatively low value of the instantaneous rate of natural mortality (M), long life span and larger maximum size (≥50.0cm TL) which sometimes reach nearly close to 56 years such as *Lutjanus bohar* **(Marriott & Mapstone, 2006; Almamari *et al.*, 2021)**. In contrast, *L. ehrenbergii* reaches only around 16 years **(D'Agostino *et al.*, 2021)**. Moreover, their maximum total size is about 35cm, the common total size is 20cm, and the maximum juvenile size is 11.7cm (matures at about 12cm) **(Allen, 1985; Dunne *et al.*, 2023)**, which unarguably makes this species the shortest-lived among the small-sized lutjanids. It also has a single spawning season occurring in the spring between March and June in the Arabian Gulf **(Grandcourt *et al.*, 2006, 2011; Vaughan *et al*., 2021)**.

It is a diurnal fish that tolerates varying levels of salinity and inhabits shallow depths of coastal areas and estuaries in the Indo-West Pacific region. Its color pattern is one of its noticeable features which is the 5-6 lines on body, along with the ocellated black spot below anterior soft dorsal fin. However, what differentiates it most from other "lined" lutjanids is that those lines are more yellowish orange, and has darker coloring on its upper body, head and around the eyes.

It is worth mentioning that the blackspot snapper is commonly found on coral reefs and rocky substrata. It is a coastal wetland species that uses the sparse fringing mangroves as daytime shelter, but vacates the security of mangroves in favor of more food-rich seagrass beds at night **(Rooker & Dennis, 1991; Nagelkerken *et al.*, 2000; Dorenbosch *et al*., 2004; Luo *et al*., 2009; McMahon *et al*., 2011)**. These types of habitats do exist in the Gulf of Suez, even if not as extensive as the rest of the Red Sea.

Blackspot snappers can be caught by various fishing gears including gillnets, handlines, cast nets, traps, and fyke nets. In Egypt, the total catch of *L. ehrenbergii* was 3 tons in year 2021, which is lower by half compared to the previous year **(GAFRD, 2022; LFRPDA, 2023)**. Even the catches of the large Lutjanidae family in 2020, 2021, and 2022 were 578, 777, and 653 tons, respectively, which is no near the average total production for this family of 2,123 tons since 1950s until now. The Lutjanidae landings in Egypt never hit its highest peak of 8,830 tons in year 2000, or came close to the family's highest catch period between 1994 and 2002 **(FAOSTAT Database, 2024)**.

Therefore, this study aimed to determine critical lengths, mortality rates (M, Z and F), exploitation ratio (E), and relative yield per recruit (Y/R)', providing essential information for fishery status evalutation of the blackspot snapper in the Gulf of Suez, Egypt, which should help contribute to its effective management and long-term sustainability.

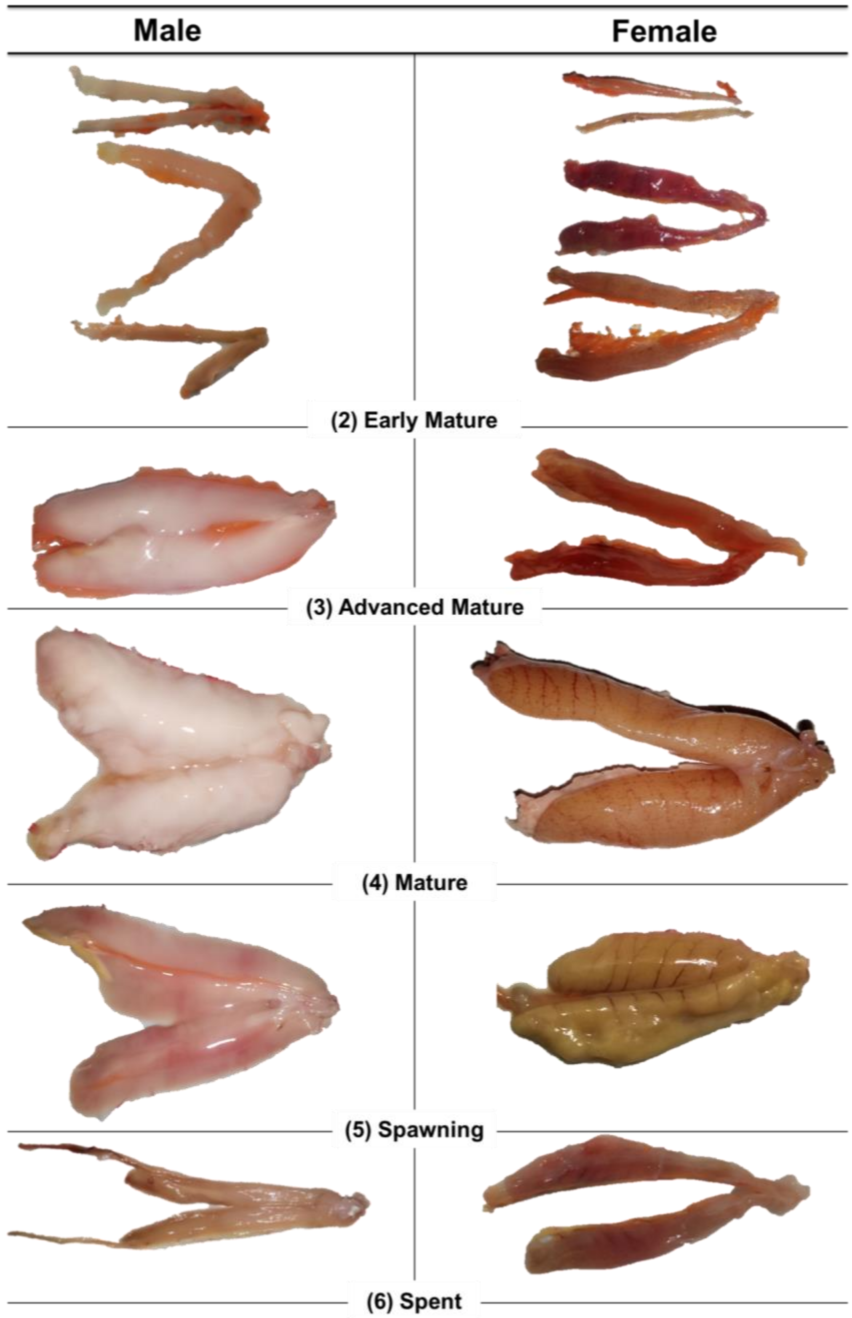
MATERIALS AND METHODS

1. Sampling and biological measurements

Samples of the species under study (Fig. 2) were consistently collected every month for a year during the active fishing season, starting from December 2022 to November 2023. These samples were obtained from landing centers in Suez and Hurghada. For each specimen, the total length (TL) was measured to the nearest 1mm, and the total weight was calculated to the nearest 0.1g. Additionally, the specimens were dissected to determine their sex and the stage of their gonadal development (Table 1).

Fig. 2. *Lutjanus ehrenbergii* external features

Table 1. *Lutjanus ehrenbergii* male and female main phases of gonadal development



2. Methods

2.1. Critical lengths and ages

The length at recruitment (L_r) was determined as the smallest blackspot snapper specimen in the catch, the length at the first capture (L_c) the length at which 50% of *L. ehrenbergii* retained in the gear was estimated by the analysis of catch curve using the method of **Pauly (1983)**, while the length at first sexual maturity (L_m) was estimated as the point on X-axis corresponding to 50% point on Y-axis on the maturation curve. Critical lengths were then converted to their corresponding ages by using a version of the **von Bertalanffy (1938)** formula:

$$\text{Critical Age} = t_0 - (1/k * \ln [1- (\text{Critical Length}/L_\infty)])$$

The growth parameters K, L_∞ and t_0 were taken from **ElKady *et al.* (2024)**.

2.2. Estimation of mortality rates

Total mortality coefficient (Z) was estimated by using three methods; **Beverton and Holt (1956)** equation, **Jones and Van Zalinge (1981)** (Analysis of the cumulative catch curve), **Pauly (1983)** (Analysis of the length converted catch curve) and all of them depend on the length frequency data. The natural mortality coefficient M was estimated as the geometric mean of four methods; **Taylor (1960)**'s method, **Ursin (1967)** formula, **Rikhter and Efanov (1976)** and **Pauly (1980)**. The fishing mortality coefficient F was estimated by subtracting the value of natural mortality coefficient from the value of total mortality coefficient as **F = Z – M**.

2.3. The Exploitation ratio

The exploitation rate was estimated by the formula suggested by **Gulland (1971)** through the following relation: **E = F / Z**

2.4. Management

2.4.1. Yield per recruit (Y/R)

The yield per recruit was estimated based on **Beverton and Holt (1957)** model. This model can be written in the form suggested by **Gulland (1969)** as follows:

$$Y/R = F\, e^{-M\,(Tc - Tr)} * W_\infty * [(1/Z) - (3S/Z+K) + (3S^2/Z+2K) - (S^3/Z+3K)]$$

2.4.2. Relative yield per recruit (Y/R)'

The relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' at different levels of E were estimated using **Beverton and Holt (1966)** model as follows:

$$(Y/R)' = E*U\,(M/K) * [1- 3U/(1+m) + 3U^2/(1+2m) - U^3/(1+3m)]$$

RESULTS AND DISCUSSION

1. Area description

The Red Sea is a narrow and long body of water situated between the Arabian Peninsula and Northeastern Africa. It stretches approximately 2,250 kilometers from 30°N to 12°30'N and from 32°E to 43°E. The sea has an average width of 208 kilometers and an average depth of 491 meters, with a maximum depth of 2,850 meters. Its total surface area is about 451,000 square kilometers **(Morcos, 1970)**. The Red Sea is connected to the Indian Ocean in the south through the Bab al Mandab strait and to the Mediterranean Sea through the Suez Canal, which opened in 1869. The Red Sea is divided into the Gulfs of Suez and Aqaba in the north, with the Gulf of Suez being wide, shallow, and muddy, and the Gulf of Aqaba being narrow and deep **(Tesfamichael & Mehanna, 2012)**. The Gulf of Suez stretches to nearly 250km from Suez in the north to Shadwan Island in the south, between 29°56' N and 27°36' N Latitudes. Its width consistently ranges between 20 and 40km, with a steady, mean depth of 45m throughout its axis **(Mehanna & El-Gammal, 2007)**.

Many fishing ports are found along the Gulf of Suez, from which Ataka is considered the most important with 36.2% contribution to the total landings of the Gulf, followed, in significance, by Hurghada fishing port **(LFRPDA, 2023)**.

2. Critical lengths and ages of *Lutjanus ehrenbergii*

The critical lengths and ages obtained estimations are shown in Table (2) and Fig, (3). The values of "L_r" were 14.3 and 17.4cm for *L. ehrenbergii* from Suez and Hurghada, respectively. These lengths were corresponding to an age of 0.63 and 0.42 year, for *L. ehrenbergii* from Suez and Hurghada, correspondingly. This means that the blackspot snappers landed in Suez enter the exploitable population at a smaller size than those landed in Hurghada. Length at recruitment is usually influenced by biological factors such as growth, which explains why *L. ehrenbergii* landed in Hurghada achieve bigger L_r at lesser time, having slightly higher growth rate value ($0.359y^{-1}$) than in Suez ($0.311y^{-1}$) **(ElKady *et al.*, 2024)**; L_r also could decrease when smaller fish are targeted.

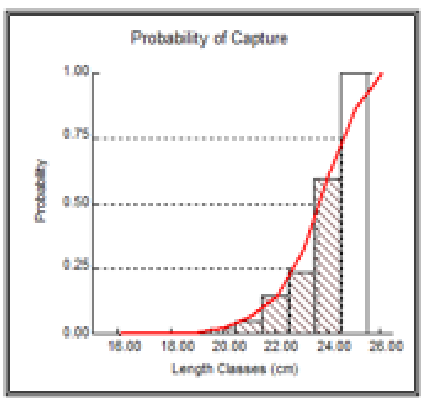
Moreover, the obtained values of "L_c" were 23.05 and 23.6cm for *L. ehrenbergii* landed in Suez and Hurghada, respectively. These values were corresponding to an age of 1.87 and 2.19 year for *L. ehrenbergii* from Suez and Hurghada, respectively. Furthermore, the obtained values of "L_m" were 22.5 and 21.9cm for *L. ehrenbergii* landed in Suez and Hurghada, respectively. These lengths correspond to 0.96 and 0.91 years, respectively. The L_c values in both areas are greater than the values of L_m, which gives the blackspot snapper population enough opportunity to grow and reproduce at least once (reach L_m) before being caught, which eventually promotes fishery sustainability. However, fish landed in Hurghada having slightly higher L_c value indicates higher selectivity.

The blackspot snapper from the two landing sites almost reach maturation at the same time, and the higher the value of L_c against L_m, the greater the possibility for spawning more than once before becoming fully vulnerable to the fishing gears of the Gulf of Suez.

Table 2. Estimations of L_r, L_c, and L_m for *L. ehrenbergii* landed in Suez and Hurghada

Parameter	Gulf of Suez	
	Suez	**Hurghada**
L_r (cm)	14.3	17.4
t_r year	0.63	0.42
L_c (cm)	23.05	23.6
t_c year	1.87	2.19
L_m (cm)	22.5	21.9
t_m year	0.96	0.91

(a)



(b)

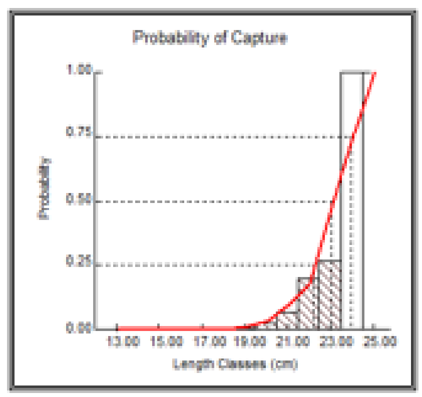


Fig. 3. Probability of capture analysis of *L. ehrenbergii* collected from **(a)** Hurghada and **(b)** Suez

3. Mortality rates of *Lutjanus ehrenbergii*

The mortality coefficients estimations for *L. ehrenbergii* landed in Suez and Hurghada are represented in Figs (4, and 5) and given in Table (3). The mean values obtained for total mortality were 1.78 and 1.38/year for *L. ehrenbergii* from Suez and Hurghada, respectively. The mean value obtained for natural mortality was 0.54/year for *L. ehrenbergii* in both Suez and Hurghada. Clearly, factors such as predation, disease, or environmental stressors *L. ehrenbergii* have been subjected to are consistent across the Gulf of Suez. The values of fishing mortality, resulting from subtracting natural mortality from total mortality, equaled 1.24 and 0.84 in Suez and Hurghada, respectively. Higher total and fishing mortality in Suez suggests that *L. ehrenbergii* is subjected to more intense fishing pressure or less effective management. It is clear that the mortality rates of the blackspot snapper in the Gulf of Suez are significantly higher than the values of **(Grandcourt *et al.*, 2011)** in Southern Arabian Gulf, but lower than the values of **Mehanna *et al.* (2017)** in Hurghada.

(a) **(b)**

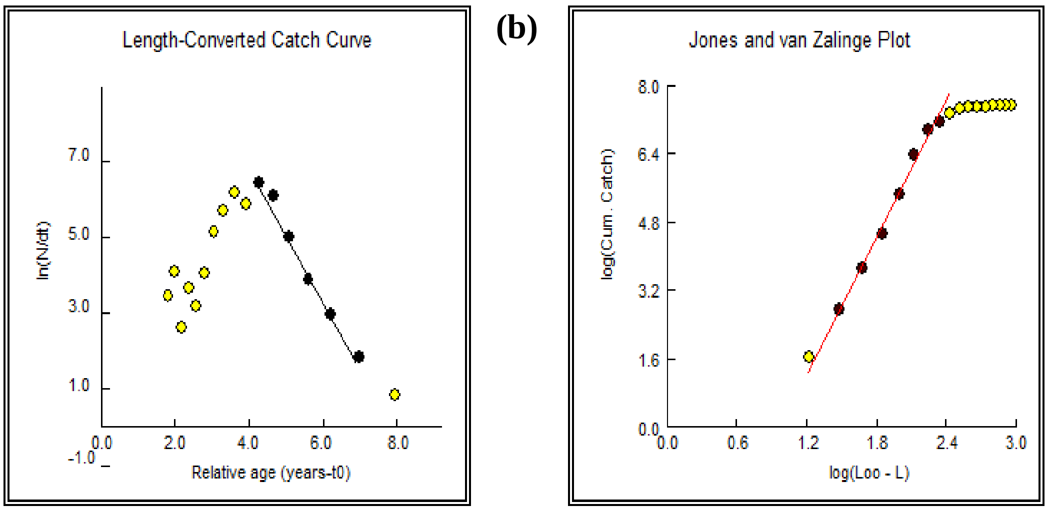


Fig. 4. Total mortality (Z) estimation of *L. ehrenbergii* landed in Suez from **(a)** Length-converted catch curve and **(b)** Jones and van Zalinge method

(a) **(b)**

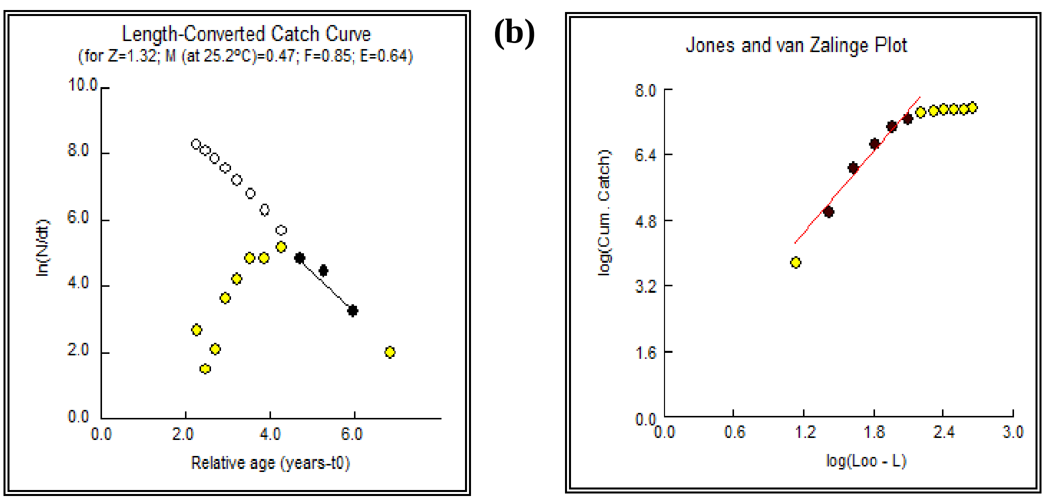


Fig. 5. Total mortality (Z) estimation of *L. ehrenbergii* landed in Hurghada from **(a)** Length-converted catch curve and **(b)** Jones and van Zalinge method

Table 3. Natural mortality (M), total mortality (Z), and fishing mortality (F) values of *Lutjanus ehrenbergii* in the Gulf of Suez and different study areas

Author	Mortality Estimation	**Z Estimation** (/year)			**M Estimation** (/year)				**F** (/year)
	Study Area	**Beverton & Holt (1956)**	**Jones & van Zalinge (1981)**	**Pauly (1983)**	**Taylor (1960)**	**Ursin (1967)**	**Rikhter & Efanov (1976)**	**Pauly (1980)' s** empirical equation	Z - M
Current Research	Suez	1.94	1.63	1.77	0.31	0.18	0.76	0.75	1.24
	Mean	1.78			0.54				
	Hurghada	1.46	1.35	1.32	0.36	0.17	0.76	0.86	0.84
	Mean	1.38			0.54				
Mehanna *et al.* (2017)	Hurghada	2.17			0.69				1.48
Grandcourt *et al.* (2011)	Southern Arabian Gulf	0.51			0.35				0.16

4. Exploitation ratio (E)

The estimated exploitation rates for *L. ehrenbergii* collected from Suez and Hurghada were 0.70 and 0.61/year, respectively (Table 4), which seem to be higher than the optimum level of exploitation ($E_{0.5}$) of 0.43 and 0.44. The high values of exploitation ratios indicate that *L. ehrenbergii* from both landing sites is overexploited, and need to be reduced by 0.27 (38.6%) and 0.17 (27.9%)/year to reach the optimum level.

The exploitation rate of *L. ehrenbergii* in Hurghada is lower than the result of **Mehanna *et al.* (2017)** which is in turn lower than that of the current study's *L. ehrenbergii* landed in Suez. This concludes that *L. ehrenbergii* landed in Hurghada have better chances of recovery from overexploitation than those collected from Suez.

Table 4. Exploitation ratio (E) estimation of *L. ehrenbergii* in the Gulf of Suez

Author	Study Area	$E_{current}$ (/y) F / Z
Current Research	Suez	0.70
	Hurghada	0.61
Mehanna *et al.* (2017)	Hurghada	0.68

5. Management

5.1. Yield per recruit (Y/R)

The results of the applied model of **Beverton and Holt (1957)** for yield per recruit analysis were 51.3 and 49.5g per recruit of *L. ehrenbergii* landed in Suez and Hurghada, respectively; which means that each Ehrenberg's fish that survives to enter the fishery at age (t_c) is expected to contribute the calculated grams of biomass to the fishery over its lifetime.

Yield curves in Fig. (6) show yield per recruit captured at different ages older and younger than the current (t_c) value. The older age at first capture (t_c = 2 and 2.5 for Suez and Hurghada) may result in slightly lower yields but promotes sustainability and allows fish to spawn before being caught. On the contrary, the younger age at first capture (t_c = 1.5 for both Suez and Hurghada) can yield higher biomass, but risks overexploiting juveniles, which may harm the sustainability of the stock in the long term. Furthermore, all curves plateau at higher "F", meaning that increasing fishing beyond this point does not substantially increase yield.

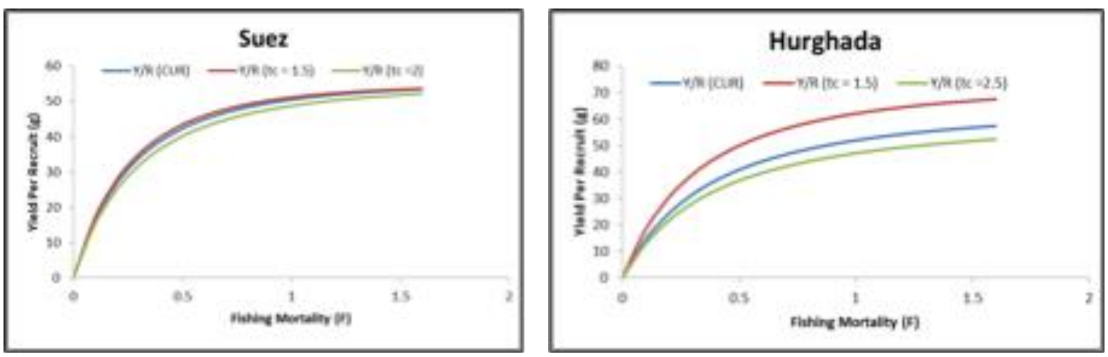


Fig. 6. Yield curves of *L. ehrenbergii* at different t_c values in the Gulf of Suez

5.2. Relative yield per recruit (Y/R)'

Relative yield per recruit (Y/R)' results of *L. ehrenbergii* collected from Suez and Hurghada are shown in Fig. (7). The values of $E_{0.5}$ (the exploitation level which will result in a reduction of the unexploited biomass by 50%) as well as E_{max} were estimated. At the current exploitation level (E = 0.70 and 0.61 /Year), the relative yield-per-recruit (Y/R)' is significantly below its maximum value. This suggests that yield efficiency is not optimal, but the population is currently overexploited as the relative biomass-per-recruit (B/R)' at this level of exploitation is very low, which indicates that the remaining biomass is critically depleted. This result is in contrast to the findings of **Grandcourt *et al.* (2011)**, who stated that *L. ehrenbergii* was exploited within sustainable limits in the Southern Arabian Gulf.

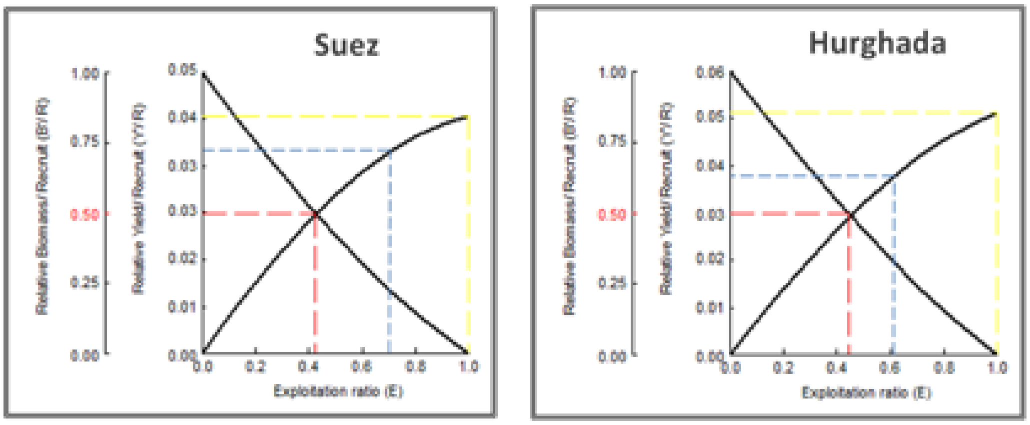


Fig. 7. Relative yield per recruit analysis for *L. ehrenbergii* in the Gulf of Suez

CONCLUSION

This part represents the conclusions drawn from findings between the blackspot snapper specimens collected from the two main landing sites of Suez and Hurghada, the key differences, and their implications.

Ehrenberg's snapper collected from Suez and Hurghada become mature at a nearly close size and age, but gets recruited and becomes vulnerable for fishing earlier in Suez than in Hurghada. The natural mortality of the blackspot snapper landed in the two areas is the same; however, higher total and fishing mortality in Suez suggests that *L. ehrenbergii* is subjected to more intense fishing pressure or less effective management. This explains the higher exploitation ratio of Suez than Hurghada, and both were higher than the optimum, which indicates that this fishery is overexploited in both regions, consequently, making Suez unsustainably producing more grams of yield per each recruit of blackspot snapper compared to the other landing site.

More exploitation might temporarily mean more yield, even though the current exploitation level is above the optimum, still the relative yield-per-recruit (Y/R)' is significantly below its maximum value; this means that yield efficiency is not optimal as the population is already exhausted. Additionally, even the relative biomass-per-recruit (B/R)' at this level of exploitation is very low, which indicates that the remaining biomass is critically depleted.

This presses for immediate measures to promote fishery health, lessen the overexploitation, and in turn sustainably increase biomass per recruit which in the long run will reflect on yields. One solution is delaying age at first capture by using larger mesh sizes or bigger hooks that target bigger fish and allow younger fish to grow and reproduce at least once before they get susceptible to capture. Stock assessment should be regularly conducted to make sure that sitting management plans and strategies are on the right tracks and to guide the decision-making in order to improve and maintain the health of such lucrative fishery.

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