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# Critical lengths and Fisheries management of *Rhabdosargus haffara* (Forsskål, 1775) from Hurghada fishing area, Red Sea, Egypt

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## ABSTRACT

The present study aimed at determining the critical lengths and the population parameters required for the management of *Rhabdosargus haffara* in the Hurghada fishing area, Red Sea, Egypt. During the fishing season 2018-2019, 466 specimens of *R. haffara* were gathered monthly from the Hurghada landing site. The length at first capture ($L_c$) was 14.0 cm, while the length at first sexual maturity ($L_m$) was 17.9 cm. The $L_c$ was greatly smaller than the $L_m$ in an indication for heavy exploitation of this species. Total mortality (Z) was estimated to be 1.98/y, natural mortality (M) was 0.66/y, and accordingly, the fishing mortality (F) was 1.32/y. The rate of exploitation (E) was calculated at 0.67 in another indication for the overfishing status of the *R. haffara* stock in the Hurghada fishing ground, Egypt. The yield per recruit model was used to confirm the stock's overfishing status and to determine the optimal fishing mortality that could save this important fishery in the Egyptian Red Sea.

## INTRODUCTION

Seabreams (family Sparidae) are ubiquitous fish found in tropical and temperate environments. This family currently has 159 species belonging to 38 genera (Froese and Pauly, 2020). The fishes in this family ranged in size from tiny to larger, and diversified in overall appearance, ranging in shape from elongate to deep-bodied. They had a wide range of colors, ranging from silver to black, yellow with golden reflections, pink to red (Al Mamry *et al.*, 2009). *Rhabdosargus haffara*, *R. sarba*, *Diplodus noct*, and *Acanthopagrus bifasciatus* are the major component of family Sparidae catch in the Egyptian Red Sea (El-Mahdy *et al.*, 2019). the sparids species in the Egyptian Red Sea are subject to a high commercial exploitation and constitute one of the main target species for both the small-scale fishery and trawling in the area. *Rhabdosargus haffara* is a member of family Sparidae which inhabits shallow waters, mainly around coral reefs, and over sandy or mud-sandy bottoms and feeds on benthic invertebrates (Sommer *et al.*, 1996).

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Despite the commercial significance of *R.haffara* species in the Egyptian Red Sea, studies and information on population dynamics and management are scarce (Mehanna, 2001 and El-Drawany, 2015). As a result, the current study was carried out in order to provide the essential information that needed for construction a short and long plan for conserving the *R. haffara* stock in the Egyptian Red Sea based on precise scientific knowledge.

## MATERIALS AND METHODS

### 1. *Collection of samples*

During the fishing season 2018-2019, 466 *Rhabdosargus haffara* fish were collected monthly from the Hurghada landing site (Red Sea, Egypt) at Hurghada city (Fig. 1). The total length was measured to the nearest cm, the total weight was measured to the nearest 0.1g, and the otolith was removed, cleaned, and stored in special envelopes with all pertinent information for age determination. The age and growth data as well as the von Bertalanffy growth parameters were derived from Osman *et al.* (2020) where the first part of this study was completed (Table 1).

**Fig. 1.** A map of the Red Sea showing the study area

**Table 1.** The von Bertalanffy growth parameters of *R. haffara* from Osman *et al.* (2020)

| $L_\infty$ | K | $t_0$ | Length-weight parameters | |
|---|---|---|---|---|
| | | | a | B |
| 30.47 cm | 0.36/y | -0.26 year | 0.0107 | 3.129 |

## *2.Methods*

### *2.1 Length and age at first capture*

The probability of capture curve (Pauly, 1984) was constructed to determine the length at first capture ($L_c$). To estimate the age at first capture $T_{c,}$ the von Bertalanffy growth equation was used to convert $L_c$ to $T_c$ as follows:

$Tc = -1/K \ Ln\ (1- Lc / L\infty) + t_0$.

### *2.2 Length and age at recruitment*

The smallest fish in the catch was considered as the length at recruitment ($L_r$), and the age at recruitment ($T_r$) was calculated by converting $L_r$ to $T_r$ using the von Bertalanffy formula as $Tr = -1/K \ Ln\ (1- Lr / L\infty) + t_0$.

### *2.3 Length at first sexual maturity*

The length at first sexual maturity (Lm), or the time when 50% of *R. haffara* reach sexual maturity, was calculated using Froese & Binohlan's (2000) spreadsheet empirical equation, where $Log\ L_m = 0.8979 * Log\ L\infty - 0.0782$. By transforming Lm to age using the von Bertalanffy growth equation, the associated age at first sexual maturity (Tm) was calculated as $Tm = t_0 - (1/k * \ln [1- (Lm/L\infty)])$.

### *2.4 Mortalities and exploitation rates*

The total mortality coefficient (Z) was calculated using two methods: cumulative catch curve analysis (Jones and Van Zalinge, 1981) and length converted catch curve analysis (Pauly, 1983). The natural mortality coefficient (M) was estimated as the geometric mean of three different methods Taylor’s method (1960), Rikhter and Efanov's empirical model (1976), and Pauly's empirical equation (1980). By subtracting the value of the natural mortality coefficient (M) from the value of the total mortality coefficient (Z), the fishing mortality coefficient (F) was calculated as $F = Z – M$. The exploitation ratio (E) was calculated by the following equation: $E = F / Z$ (Gulland, 1971).

### *2.5 Fisheries Management*

### *2.5.1 Relative yield per Recruit (Y/R)’*

The relative yield per recruit (Y/R)' of *R. haffara* was analysed using the Beverton and Holt (1966) model as follows:

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

Where: (Y/R)' = relative yield per recruit, $m = (1-E) /(M/K) = K/Z$ and $U =1– (Lc/L\infty)$.

### *2.5.2 Yield per recruit (Y/R) model*

The steady-state model of of Beverton and Holt (1957) using the Gulland (1969) formula as mentioned in Sparre and Venema (1992) was applied, the formula expressed by the following equation:

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

Where Y/R = yield per recruit, $S = e^{-k\ (Tc – to)}$, k = von Bertalanffy growth parameter, Tc= age at first capture, Tr = age at the recruitment, $t_0$ = age at which the length is nil, $W\infty$ = asymptotic body weight, F = fishing mortality coefficient, M = natural mortality coefficient and Z = total mortality coefficient.

The two parameters "F" and "Tc" can be controlled by fishery managers because the fishing effort is proportional to "F" and the "Tc" is related to the mesh size.

The model allows for the calculation of Y/R with variable Tc and F inputs, as well as determining the impact of the various input values on *R. haffara's* Y/R. Furthermore, Beverton and Holt's biomass per recruit (B/R) were taken into account, and the impact of mesh size on *R. haffara* growth was evaluated.

### *2.5.3 Virtual population analysis (VPA)*

We used the values L∞, K, F, $t_0$, a and b for *R. haffara* in the FiSAT program to perform virtual population analysis on length-frequency data. The biomass (tonnes), population (tonnes), fishing mortality (F), and catch (tonnes) were all calculated using VPA.

## RESULTS AND DISCUSSION

### *1. Critical lengths*

According to the resultant curve derived from the catch curve (Fig. 2), the length at first capture Lc was estimated at 14.0 cm TL for *R. haffara* from Hurghada fishing area and the age at first capture Tc was computed as 1.45 years. The length at recruitment Lr was found to be 12 cm and the corresponding age at recruitment Tr was 1.13 years. On the other hand, the length at first sexual maturity Lm was determined as 17.9 cm and the corresponding Tm was 2.2 year.

*R. haffara* had a length at recruitment (Lr) of 12 cm in this investigation. This short length indicates overfishing, as they are caught before they have grown large enough to contribute significantly to the biomass of the stock. Furthermore, the estimated length at first capture (Lc) was found to be less than the estimated length at first sexual maturity (Lm = 17.9 cm), indicating that this species didn’t have the chance to spawn at least once in the fishery before being fished.

### *2. Mortality and exploitation rates*

The total mortality coefficient of *R. haffara* determined by two different methods (Fig. 3); the cumulative catch curve of Jones and Van Zalinge (1981) and the length converted catch curve of Pauly (1983) was 1.67/y and 2.28/y, respectively with an average of 1.98/year. Rikhter & Efanov's, Pauly's, and Taylor's methods yielded natural mortalities at 0.76, 0.86 and 0.36 /y, respectively with a geometric mean of 0.66/year. The value of fishing mortality was 1.32/y. F had a high value, indicating a high level of exploitation.

In the current study, the total mortality value (Z = 1.98 /y) is higher than the values estimated by the previous studies. Mehanna (2001) in the Suez Bay and El-Drawany (2015) in Lake Timsah (Suez Canal, Egypt), gave Z-values equal 1.22 /y in both studies. This increase in Z-values is logic as the fishing activities increase from year to year. The current natural mortality coefficient (M = 0.66 /y) is also higher than that estimated by

Mehanna (2001) (M = 0.4 /y) and El-Drawany (2015) (M = 0.29 /y). Natural mortality rates change depending on the density of predators and competitors, whose presence is influenced by fishing operations, in different places (Sparre & Venema, 1998).

When compared to fishing mortality reported by Mehanna (2001) at F = 0.90 year$^{-1}$ and El-Drawany (2015) at F = 0.93 /y, the value of fishing mortality (F =1.32 /y) was extremely high. This is due to the excessive fishing effort on the *R. haffara* stock in the Egyptian Red Sea off Hurghada.

The exploitation ratio of *R. haffara* was estimated at 0.67, which is significantly higher than the optimum one (E = 0.5). The exploitation rate is critical for determining the state of any fish stock, as it defines which stocks are overexploited and which are underexploited. The exploitation rate for *R. haffara* was 0.67, which is greater than the optimum one suggested by Gulland (1971). He stated that for F = M, the optimal exploitation rate for every exploited fish stock is around 0.5. As a result, the current level of exploitation (E = 0.67) is much higher than the optimum one $E_{0.5,}$ indicating that the stock of *R. haffara* is overexploited.

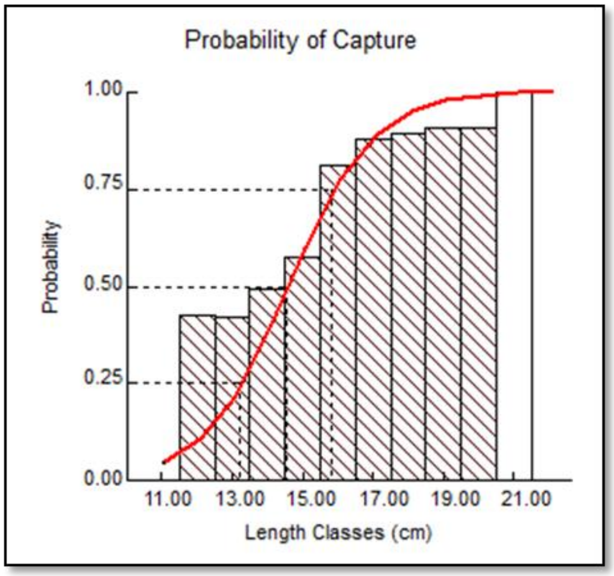

**Fig. 2.** Length at First capture (Lc) of *R. haffara* from Hurghada, Red Sea, Egypt.

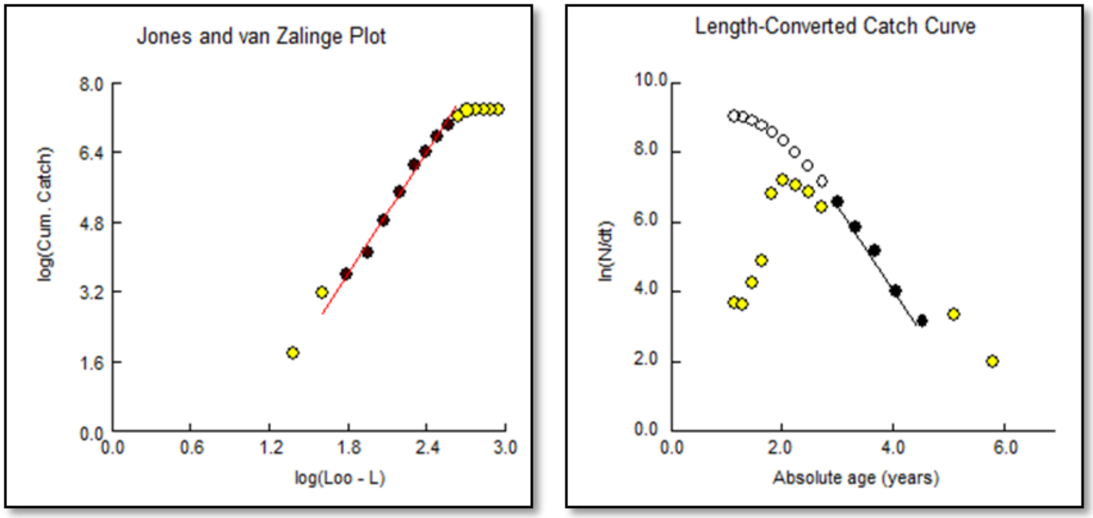

**Fig. 3.** Z-estimation of *R. haffara* from the Hurghada, Red Sea, Egypt

## *3. Fisheries management*

### *3.1 Relative Yield per Recruit (Y/R)'*

The model of Beverton and Holt (1966) was applied to estimate the relative yield per recruit and biomass per recruit of *R. haffara* from Hurghada fishing area. This model allows a relative prediction of the long term catch weights and stock biomass under different exploitation rates. The maximum (Y/R)' was obtained at an exploitation rate 0.7, which is higher than the present level of exploitation rate (0.67). $E_{0.5}$ of *R. haffara*, which conserves 50% of the spawning stock biomass was calculated to be 0.35. The current level of exploitation (E= 0.67) is much higher than $E_{0.5}$ (E= 0.35). To protect the spawning stock biomass, the exploitation rate of *R. haffara* should be reduced from 0.67 to 0.35 (48%) for management purposes (Fig. 4).

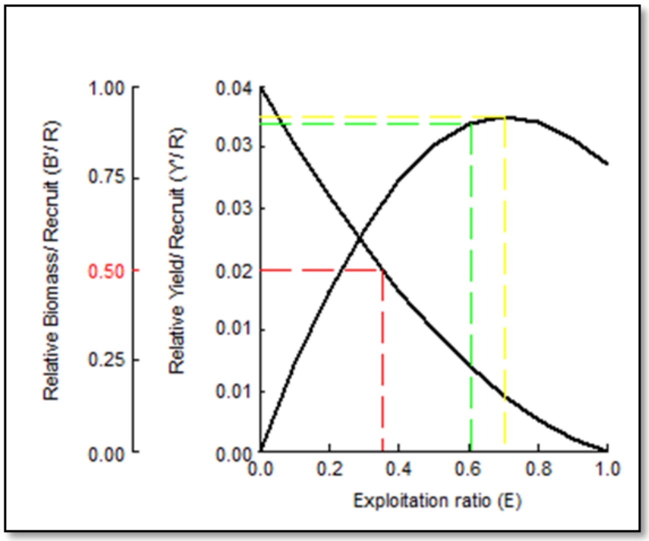

**Fig. 4.** Relative yield per recruit for *R. haffara* from Hurghada, Red Sea, Egypt.

### *3.2 Yield per recruit*

The yield per recruit of *R. haffara* was determined using the model of Beverton and Holt (1957) by applying the Gulland formula (1969). The results (Fig. 5) indicate that, the yield per recruit was zero when fishing mortality was zero. The increase of fishing mortality is associated with an increase in yield per recruit until it reaches its maximum value then, the yield per recruit decreases whatever the fishing mortality increased. According to the findings, the maximum Y/R was obtained at fishing mortality coefficient equal to 1.05. This means that the present level of fishing mortality coefficient (1.32/y) is higher than that which gives the maximum Y/R and it must be reduced by about 20.5% to obtain the maximum yield per recruit.

To investigate the impact of age at first capture (Tc), which is closely related to the estimation of the optimum mesh size, different values of Tc were applied. Different age at first capture values (0.5 and 2.5 years), along with the current value (1.45 years) were applied. The yield per recruit increased with the increase of age at first capture. This means that the present level of Tc is not appropriate for the stock of *R. haffara* in Hurghada fishing area and it must be raised to more than 2.2 year (age at first sexual maturity).

Also, the yield per recruit of *R. haffara* was calculated using different values of natural mortality coefficient (0.33 and 0.75 / y) with the current level of natural mortality coefficient (0.66 / y) to assess the effect of changing the natural mortality coefficient (M) on the yield per recruit of *R. haffara* (Fig. 6). The results showed that as the natural mortality coefficient rises, the yield per recruit declines. A higher yield per recruit (47.72 g) would be attained at the present level of fishing mortality coefficient (1.32/ y) and the current age at first capture (1.45y) with a lower level of natural mortality coefficient (0.33/ y) instead of the current level (0.66 / y). This means that the environment where this stock lives should be protected and the water quality should be monitored to reduce the natural mortality.

The yield per recruit analysis showed that the *R. haffara* stock in the Egyptian Red Sea off Hurghada is overexploited and it exploited at a mean size lower than that at which full growth potential is reached. This highlighting the need for a re-assessment of mesh size limitations and reducing the fishing mortality to avoid future losses in stock productivity and landings.

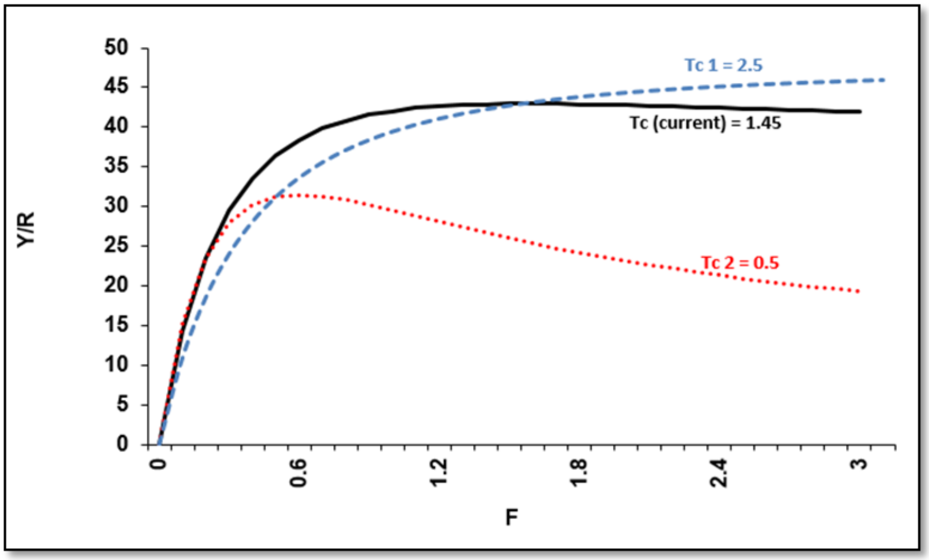

**Fig. 5.** Yield per recruit (g) of *R. haffara* collected from Hurghada, Red Sea, Egypt as a function of fishing mortality (F) and different ages at first capture (Tc)

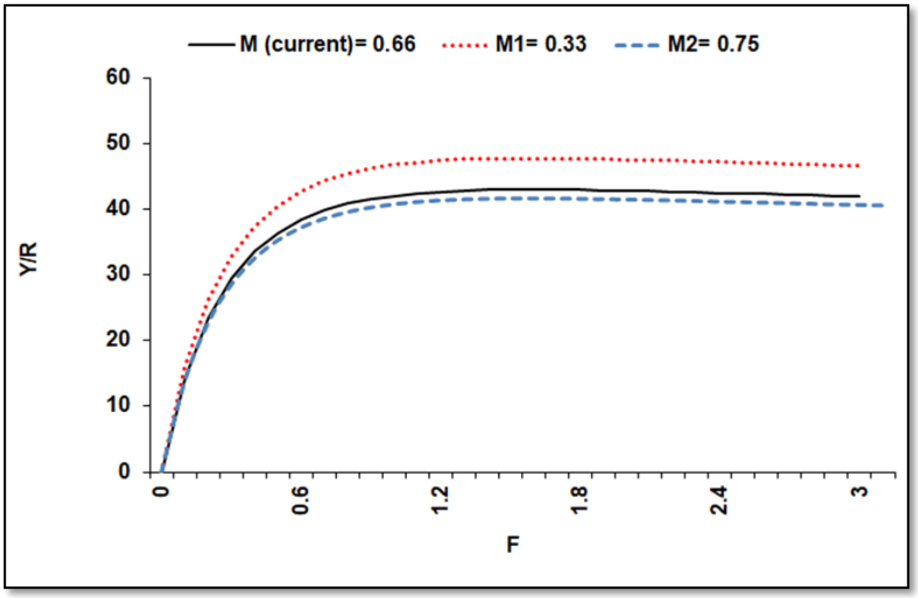

**Fig. 6.** Yield per recruit (g) of *R. haffara* collected from Hurghada, Red Sea, Egypt as a function of fishing mortality (F) and different natural mortalities (M)

### *3.2.3 Virtual population analysis*

Virtual population analysis (VPA) data were utilised to make management decisions and provide more information about the status of fish stocks in terms of growth, recruitment, and overfishing (Chen *et al.*, 2008). Figure 7 should that, natural mortality is the only cause for loss of *R. haffara* at lengths from 12 cm to 15 cm. *R. haffara* was caught by fishing gears in sizes from 15 cm upwards, with the highest quantities in lengths from 17cm to 19 cm. *R. haffara* had the greatest fishing death rates of 1.34 and 1.51 /y, which corresponded to lengths of 21 and 26 cm, respectively. Smallest length groups have lower catches (harvesting rate) than the largest ones (Table 2), indicating that the fishing mortality rate is size specific, as found by Amponsah *et al.* (2017).

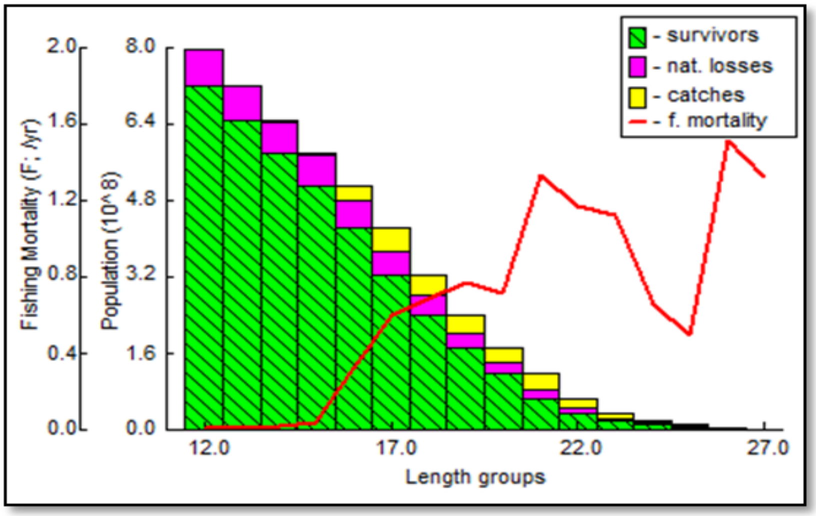

**Fig. 7.** Length-structured Virtual Population Analysis (VPA) for *R. haffara* from Hurghada, Red Sea, Egypt.

## CONCLUSION

In conclusion, this study highlights the basic data on mortality and exploitation rates, yield per recruit analysis and virtual population analysis of *Rhabdosargus haffara* in Hurghada fishing area, Red Sea. It can be inferred that the stock of this species is overexploited, and urgent management actions, such as lowering the current level of fishing mortality and increasing the length at first capture, would be beneficial in preserving this valuable fishery resource. Also, to sustain the spawning biomass of *R. haffara*, fishing effort should be regulated and reduced. The present evaluation suggests a target reference point of not less than a 50% reduction in fishing effort.

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