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Population Dynamics and Assessment of the Snubnose Emperor *Lethrinus borbonicus* (*L. bungus*) from the Gulf of Aqaba, Egypt

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ABSTRACT

Knowledge about the life history of exploited species is fundamental to improving fisheries management. The population dynamics and status of the snubnose emperor (*Lethrinus borbonicus*) in the Gulf of Aqaba, Egypt were assessed using the size at-age data. The whole sagittal otoliths were characterized by alternating translucent and opaque bands that were validated as annuli. Comparisons of age and growth characteristics recorded no significant differences (P>0.05) between the sexes. The von Bertalanffy growth parameters for pooled data were K= 0.476/year, L_∞= 35.80 cm TL and t_0= -0.23 year. The mean size at which the fish attained sexual maturity for *L. borbonicus* was 20.75 cm TL. The mean size at first capture was 24.05 cm, which was greater than the size at first sexual maturity indicating the healthy status of *L. borbonicus* stock in the Gulf of Aqaba. The fishing mortality rate for *L. borbonicus* (0.70/yr) was substantially greater than the target F_{opt} (0.36/yr) and limit F_{limit} (0.48/yr) estimates. The snubnose emperor stock was in its optimum situation as the current exploitation rate was 0.49/yr. The results of the study are important to fisheries management authorities in the region since they will contribute to planning the regional fishery management policies in Egypt.

INTRODUCTION

The Egyptian sector of the Red Sea is about 1080km from Suez in the north to Mersa Halayab in the south; it has three main fishing grounds: the Gulf of Suez, Foul Bay and the Gulf of Aqaba. While, the Gulf of Suez and proper Egyptian Red Sea from Hurghada to Halayeb are heavily exploited, and all the commercial fish species in these areas are over-exploited (**Mehanna, 2021**); whereas, the Gulf of Aqaba is considered as an unexploited fishing ground. The Gulf of Aqaba (Fig. 1) is enclosed between 28°45′N 34°45′E / 28.750°N 34.750°E. It is a semi-enclosed, deep, narrow body of water of approximately 180km long, extending from the Protectorate of Ras Mohammed in the south to Taba in the north (**Hamouda & El-Gharabawy, 2019**). It has a maximum width of 24km and a depth of 1,850m at its deepest point, with a surface area of 239km^2. The Gulf is characterized by its high diversity where more than 100 coral species, 800 fish species, several crustaceans and mollusks species, dolphins, whales, dugongs and sharks are found. The present annual fish yield of the Egyptian coast of Aqaba Gulf is reported with 46 ton (**GAFRD, 2020**), which is very low in respect to the fishing area of the gulf. Commercial fish populations in the Egyptian sector of the gulf showed a seasonal variation in terms of dominant species and catch composition.

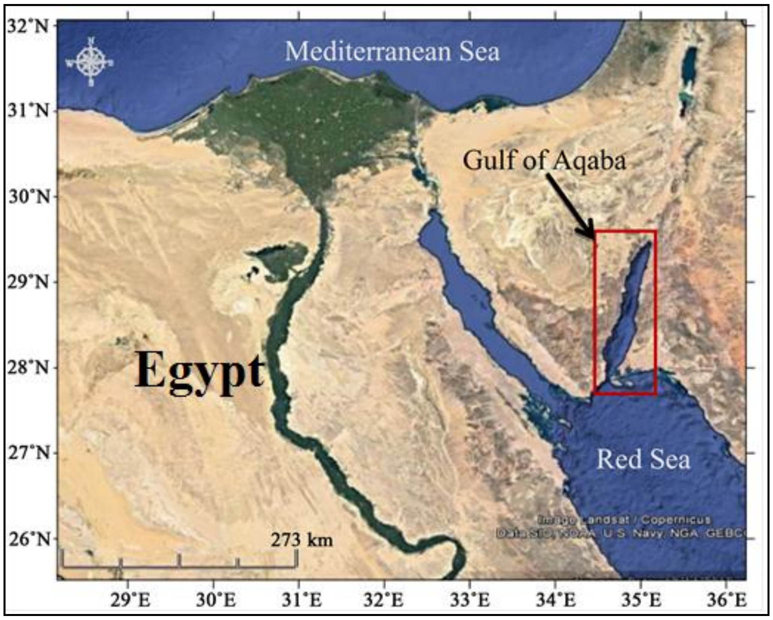

Fig. 1. The Gulf of Aqaba (study area)

Fishes of the family Lethrinidae (emperors) are abundant in tropical and subtropical Indo-Pacific waters and occur in a range of marine environments, including reefs, seagrass beds, estuaries and mangroves (**Young & Martin, 1982; Kulmiye *et al.*, 2002**). The family is comprised of 39 species worldwide, with 29 species in the most common genus (*Lethrinus*) (**Carpenter & Niem, 2001**). The snubnose emperor *Lethrinus borbonicus* (Valenciennes, 1830) is distributed throughout the Indian Ocean including the Red Sea, Persian Gulf, South Africa and east to the North Bay Reef, Andaman and Nicobar Islands (**Froese & Pauly, 2023**). It is found in a variety of habitats including sandy areas near reefs during daytime, and sometimes in small groups. At night, they are solitary and range over reef-flats and slopes, where they feed primarily on echinoderms, mollusks and crustaceans (**Carpenter & Allen, 1989**). Lethrinid species form an important part of fisheries landings in the Gulf of Aqaba, where they are caught with a variety of gears such as gill and trammel nets and lines. Collection of catch-and-effort data for the gulf fisheries in Egypt was not done, and the recorded data in the GAFRD annual reports don’t reflect the real data of the area. Therefore, the use of statistical catch-at-age methods can’t be used for conducting assessments at the species level. The lack of appropriate data on most stocks underscore the need to assess the fisheries resources of the gulf.

Life-history information on targeted fish species are required for fisheries management and represent a basis for guiding fisheries assessments and harvest strategies. Therefore, the purpose of this study was to derive age-based life-history information from fishery dependent collections of snubnose emperor *L. borbonicus* from the Aqaba Gulf, Egypt. The principal objectives focused on estimating growth, life span and mortality to evaluate the status of *Lethrinus borbonicus* and provide biological and targeting referencial points required for its management.

MATERIALS AND METHODS

The catch data from landing points along the fishing area from south Taba to Nuwaibaa was monthly recorded from September 2021 to February 2023. Boats were randomly selected at the landing points along the area from Taba to Nweibaa, and all catch of these boats was taken. For each specimen, total length was measured to the nearest 0.1cm, and the total body mass was recorded to the nearest gram. Sagittal otoliths were surgically extracted from each specimen for age determination. Otoliths were cleaned with ethanol and stored dry in individually labeled vials. Growth was investigated by fitting the von Bertalanffy growth function (**von Bertalanffy, 1938**) to size-at-age data using standard nonlinear optimization methods. The model was fitted to each sex separately and to sexes combined. The von Bertalanffy growth function is defined as follows: $L_t = L\infty\ (1-e^{-K(t-t_0)})$, where Lt is the length at time t; L∞ is the asymptotic length; K is the instantaneous growth coefficient, and t_0 is the hypothetical time at which length is equal to 0. Growth curves were compared between sexes by using the analysis of residual sums of squares, following the method of **Chen *et al.* (1992)**. The growth performance index (ø’) (**Gayanilo *et al.*, 2005**) was calculated in order to provide a basis to compare growth characteristics in terms of length ø'= LogK + 2Log L∞. Parameters of the length-weight relationship were obtained by fitting the power function; $W = aL^b$ to length and weight data, where W is the total weight; L is the total length, and a and b are constants determined empirically. The annual instantaneous rate of total mortality (Z) was determined with the age-based catch curve method (**Beverton & Holt, 1957**) and length based catch curve method (**Pauly, 1983**). Natural mortality coefficient (M) was determined using the the empirical equation derived by **Hoenig (1983)** and the formula of **Lorenzen (1996)**. The annual instantaneous rate of fishing mortality (F) was calculated as F= Z-M. The exploitation rate (E) was calculated as the proportion of the fishing mortality in relation to total mortality (E= F/Z). The length at first capture L_c was estimated using catch curve analysis (**Pauly, 1984**), while the length at first sexual maturity was estimated using the formula of **Froese and Binohlan (2000)**. The **Beverton and Holt (1966)** yield-per-recruit (YPR) model modified by **Pauly and Soriano (1986)** was used to estimate the size at maximum yield per recruit and to predict the effects of increasing the mean size at first capture on the mean size at first sexual maturity and determine at which yield per recruit it would be maximized. The exploitation rates corresponding to F_{opt} and F_{limit} (E_{opt} and E_{limit}) were calculated and used to estimate the relative biomass per recruit for the species. Precautionary target (F_{opt}) and limit (F_{limit}) biological reference points were calculated as 0.5 and 2/3 M, respectively, and they were used to assess the resource status by direct comparison with the current fishing mortality rates established for the studied species.

RESULTS AND DISCUSSION

Egyptian fisheries are currently under pressure since all commercially important fish stocks are declining. At the same time, the management and regulation of the fisheries are getting more complicated every year. In fisheries management, the reliability of scientific advice is highly dependent on the quantity and quality of data that are available for stock assessment (**Mehanna, 2011**). Compared to other harvested families in tropical fisheries globally, lethrinids are among the most studied on coral reefs with regard to life-history information as a necessary input for fisheries management. The information presented in this study would provide detailed life-history data and demographic structure for one of commercially important lethrinid species (*L. borbonicus*) for the first time in the Gulf of Aqaba, Egypt.

1. Age and growth

Alternating translucent and opaque growth increments were observed in the sagittal otoliths of *L. borbonicus* when viewed with transmitted light under low-power magnification. One growth increment consisting of an opaque and translucent zone was formed on an annual basis. The maximum age estimates determined from counts of opaque and translucent bands were 5 years for males and females. A comparison of the growth characteristics between sexes revealed that there were no significant differences in parameter estimates for the studied species ($P> 0.001$). The maximum estimated age was five years, and the respective mean lengths at age were 15.81, 23.19, 28.34, 31.18 and 32.74cm at 1st, 2nd, 3rd, 4th and 5th year, respectively, while the age of full recruitment was the age of two years (Fig. 2). **Salem (1990a)** gave mean back-calculated lengths of 11.404, 15.236, 18.915, 21.171 and 23.108cm TL for the age groups from 0 to 4, respectively. **Amin (2002)** recognized five age groups in the scales of *L.bungus (borbonicus)* in the Gulf of Suez, with mean lengths of 15.99, 22.42, 26.79, 29.55 and 31.51cm. These records are relatively different than those recorded in the present study, which may be attributed to the difference in length composition and the maximum observed length among these studies.

Given that no significant difference was detected between sexes in respect to age, growth and length distribution, all calculations were conducted for combined sexes. Growth of pooled data of *L. borbonicus* (Fig. 3) can be described by the von Bertalanffy growth equation as follows: $L_t= 35.80\ (1-e^{-0.476\ (t+0.23)})$. According to **Pauly (1983)**, reasonable values of L∞ can be empirically obtained, using the relation $L_{max}/0.95$, where L_{max} is the maximum observed length in the catch. The growth performance index (Φ') was 2.79, which indicates the suitability of the environmrntal conditions such as pollution and food availability for the growth of this species.

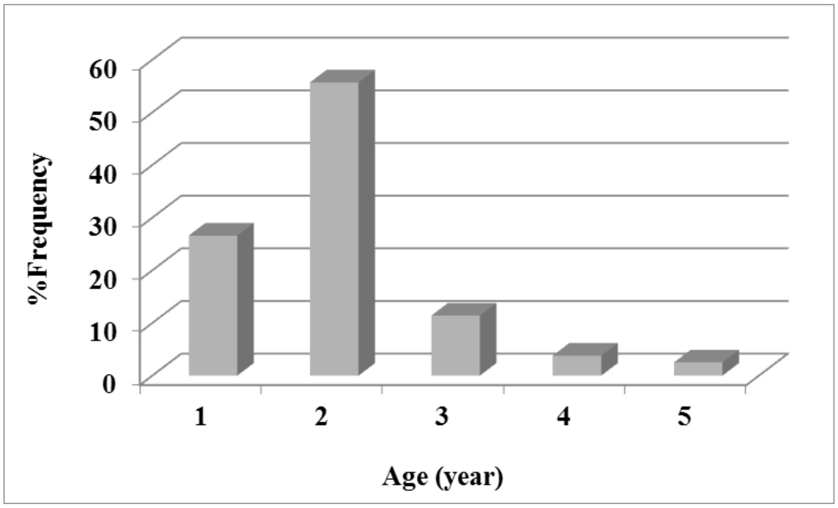

Fig. 2. Age composition of *Lethrinus borbonicus* in the Gulf of Aqaba

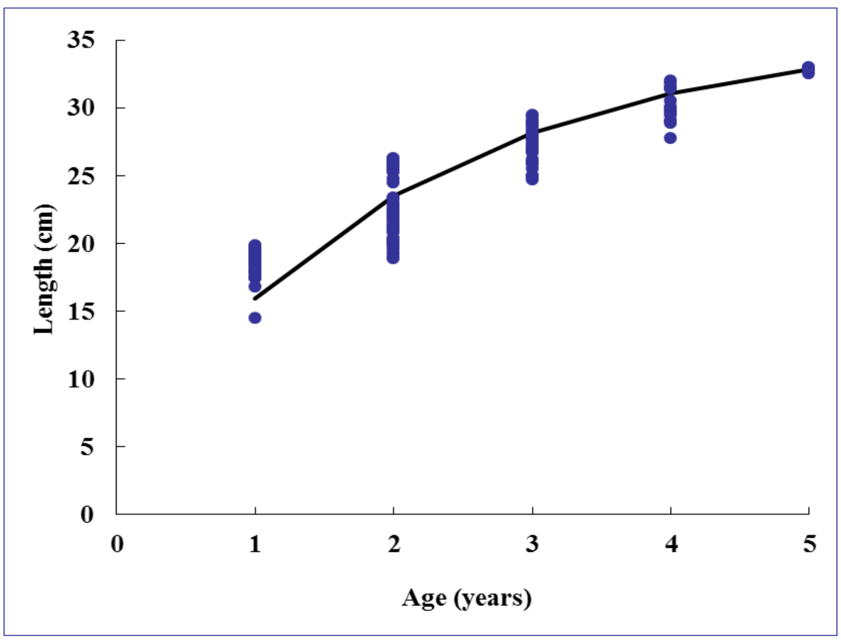

Fig. 3. The growth curve of *Lethrinus borbonicus* from the Gulf of Aqaba

2. Length frequency distribution

The total number of snubnose emperor caught from the Gulf of Aqaba was 2000 individuals, consisting of 766 males and 1234 females with an overall sex ratio of 1:1.61. The length and weight of males ranges were 16- 33cm and 50- 600g, respectively. Whereas, those of females were 14.5- 33cm and 45- 620g, respectively. The fish were grouped into one cm size groups (Fig. 4). The group sizes from 21 to 28 cm were the most dominant compared to the other groups for both sexes; those bigger than 29cm TL were represented in few numbers. The mean TL of male population (25.15±4.96 cm) did not significantly differ from that of female population (24.59±4.38 cm) (independent t-test; *P*> 0.01). The maximum observed length and the average size of the population in the Gulf of Aqaba were higher than those reported for the snubnose emperor in proper Red Sea (**Salem, 1990a, b; Mehanna, 2011**) and the Gulf of Suez (**Amin, 2002**).

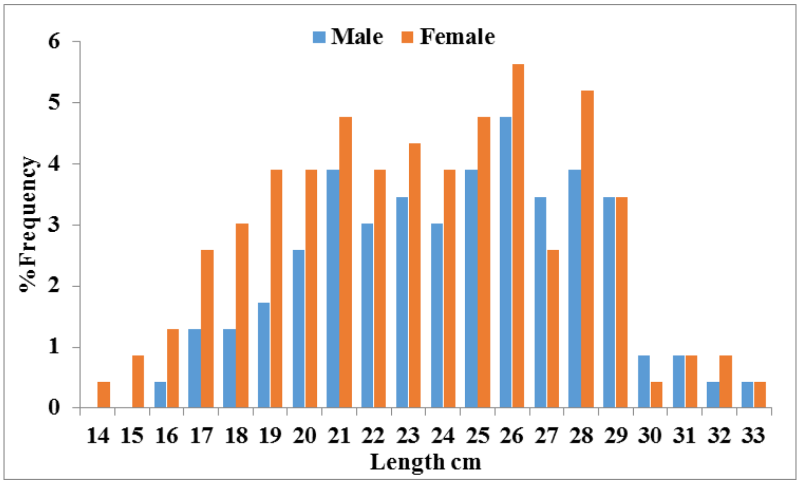

Fig. 3. Length frequency distribution of *Lethrinus borbonicus* from the Gulf of Aqaba

3. Length-weight relationship LWR

The total weight measurements varied from 50 to 600g, with an average of 279±107.33 for males, while they fluctuated from 45 to 620g, with an average of 239.44±111.26 for females. The relationship between total length and body weight (Fig. 4) was highly significant (r^2=0.98). The slope of the relationship b = 3.158, 3.2257 and 3.1796 for males, females and sexes combined, respectively. The 95% confidence intervals of the slope b indicate that the growth of this species is +ve allometric.

4. Mortality and exploitation rates

The mean value of the total mortality coefficient (Z) estimated from the two different methods was 1.42/year for sexes combined. While, the geometric mean of natural mortality coefficient (M) was $0.72y^{-1}$, and accordingly the value of fishing mortality coefficient (F) was $0.70y^{-1}$. The exploitation rate (E) can be defined as the proportion of harvestable-sized fishes that are annually removed from a population through different fishing activities (**Meyer & Schill, 2014**). The exploitation rate was computed as 0.49. The F value observed in the present study was slightly lower than M; as a result, the value of E_{cur} was found to be lower than the optimum exploitation rate (0.5) reported in the study of **Gulland (1971)**. Thus, the current values of exploitation rate and fishing mortality revealed that, the snubnose emperor fishery in the Gulf of Aqaba is operated around its optimum situation. This is acceptable because the Gulf of Aqaba in Egypt is considered an unexploitable fishing ground and needs a proper management plan for its sustainable use.

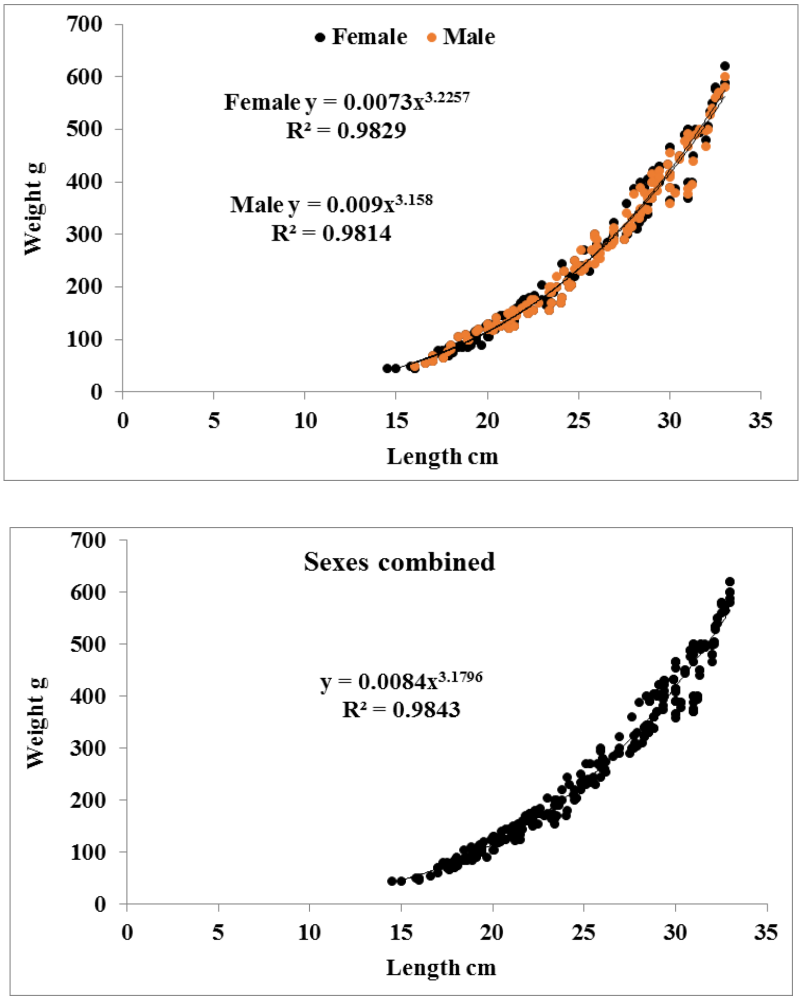

Fig. 4. Length- weight relationship of *Lethrinus borbonicus* from the Gulf of Aqaba

In the present study, the high values of M were correlated with the high K values of *L. borbonicus*. **Beverton and Holt (1957, 1959)** found that, the fast growing fish species of high K- values have high values of natural mortality. The M/K ratio of *L. borbonicus* from the Gulf of Aqaba (1.52) was in the range of 1.5 - 2.5 given in the study of **Beverton and Holt (1959)**. The specified precautionary target (F_{opt}= 0.5M = 0.36) and limit (F_{limit}= 2/3M = 0.48) values are considered to be more appropriate biological reference points in light of the constraints of the yield-per-recruit model. The current fishing mortality rate estimated for *L. borbonicus* (0.70/yr) was significantly greater than both the target F_{opt} and limit F_{limit} biological reference points. Therefore, we should be careful if we decide to implement any regulatory measures.

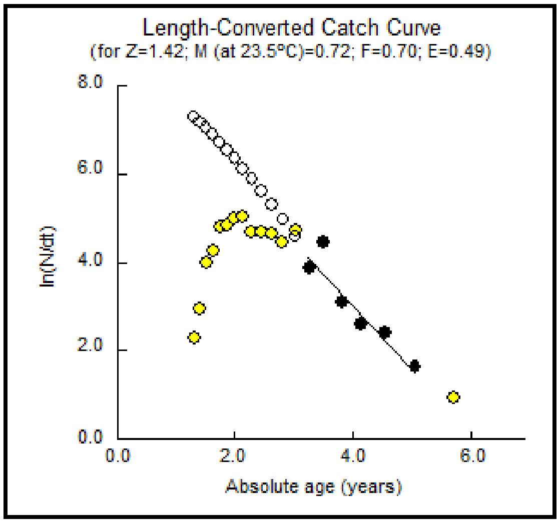

Fig. 5. Mortality and exploitation rates for pooled data of *Lethrinus borbonicus* from the Gulf of Aqaba

5. Length at first capture (Lc)and at first maturity (Lm)

The total length at first capture (the length at which 50% of the fish are vulnerable to capture) was estimated as a component of the length converted catch curve analysis. The value of L_c obtained was 24.05cm TL (Fig. 6). The estimated Lc for *L.borbonicus* in the Gulf of Aqaba is relatively high, indicating under-exploitation situation. The length at first sexual maturity was estimated based on the L∞ value as 20.75cm TL, which is corresponding to an age of 1.59 year.

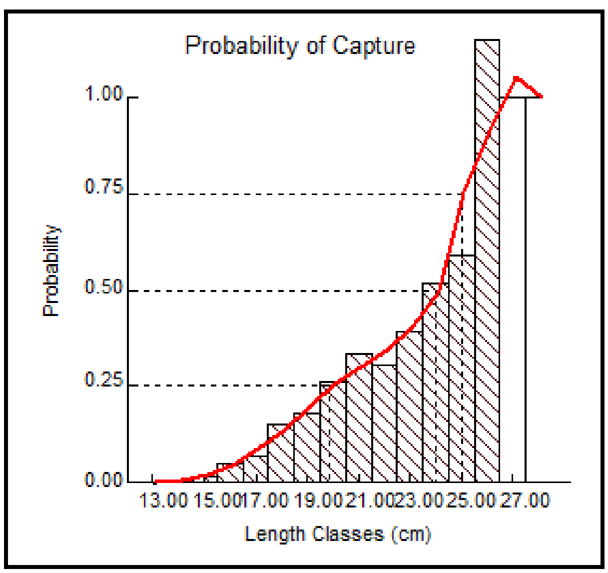

Fig. 6. Length converted catch curve and probability of capture for *Lethrinus borbonicus*

6. Virtual population and relative yield per recruit analysis

The virtual population analysis (Fig. 7) showed that younger cohorts or smaller individuals of snubnose emperor were more susceptible to natural mortality caused by predation, pollution, or disease than fishing mortality. However, snubnose emperor mortality due to fishing starts at 14cm TL, but at this size, the death of species is mainly due to natural causes. The fishing mortality begins to dominate at length ranging from 21.0cm, with a maximum value at size 26cm. The dominance of death due to fishing operations starting at 21.0cm in size is an indicator that this species was caught after sharing in the spawning activities for at least one time.

Relative yield per recruit analysis (Fig. 8) showed that a higher catch of snubnose emperor could be achieved with the increase of fishing effort along the Egyptian coast of the Gulf of Aqaba. Before any increase in fishing effort, all the required analysis shoud be conducted such as the spawning stock biomass, which is essential for maintaining the recruitment in the future. In addition, since the fishery in the Gulf of Aqaba is multispecies fishery, all other commercial stocks of finfish in the Gulf should be assessed. Thus, it could be said that, presently, the stock of snubnose emperor is operating around its optimum situation but needs more detailed study about the spawning behavior, fecundity, feeding habits and recruitment to conserve and develop its fishery.

$E_{0.5}$ represents exploitation rate at which B/R reduces by 50% compared to virgin stock, i.e. to the level which theoretically maximizes surplus production (**Pauly, 1984**) and can be used as a proxy for the optimum sustainable yield (OSY) (**Dadzie *et al.*, 2005**). In the present study, the optimum biomass of *L. borbonicus* can be maintained at $E_{0.5}$ of 0.42, which is slightly smaller than the current E. From the point of fisheries management, $E_{0.5}$ is considered a target reference point to conserve the spawning stock biomass.

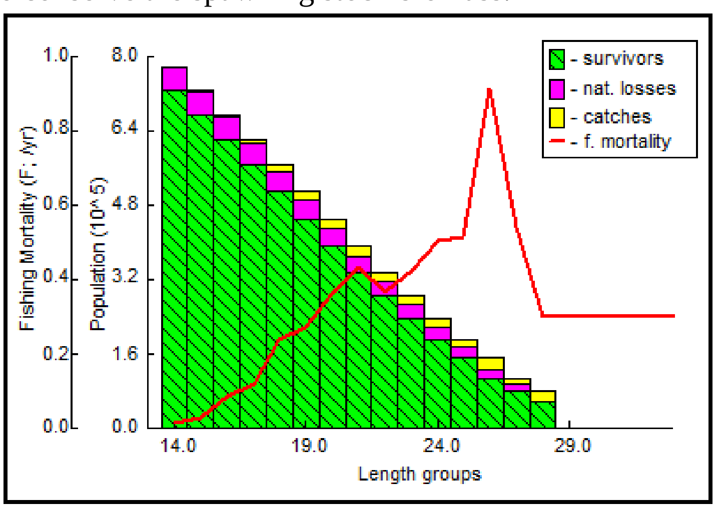

Fig. 7. Virtual population analysis VPA of *Lethrinus borbonicus* in the Gulf of Aqaba

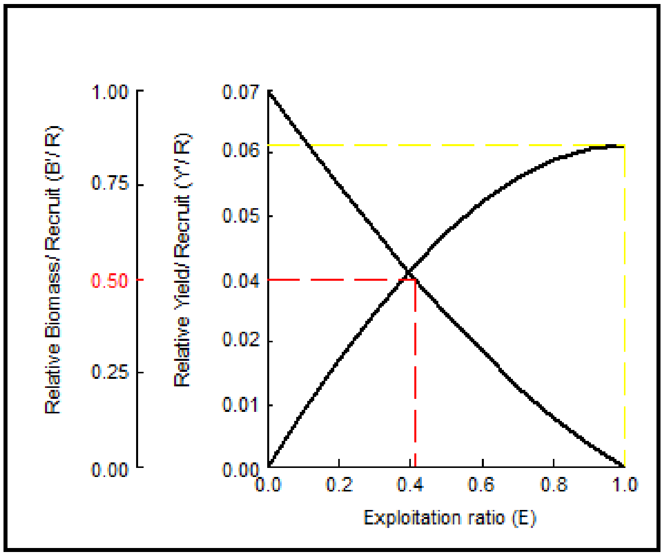

Fig. 8. Relative yield per recruit analysis of *Lethrinus borbonicus* in the Gulf of Aqaba

CONCLUSION

In conclusion, this study provided basic biological data that would aid in sustainable fishery management of *L. borbonicus* in the Gulf of Suez, Egypt.The results showed that this species in the Gulf of Aqaba is exploited around its optimum level. The possible recommendations here are: detailed precise multi-species fishery assessment should be conducted and a sampling programme for the commercial landings by species should be established. Additionally, the impact of the fishery independent factors, such as predation and other changes in environmental parameters on the growth and recruitment should be investigated. Furthermore, there is an urgent need to improve the national statistics records on catch and fishing effort. All unreported and unregulated harvest of commercial species exploited in the Gulf should also be monitored and controlled.

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