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Fisheries Biology of the Slender Emperor *Lethrinus variegatus* (valenciennei, 1830) inhabitant in the Gulf of Suez, Egyptian Red Sea

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ABSTRACT

A total of 500 specimens of *Lethrinus variegatus* were collected from Attaka fishing port, Gulf of Suez, Egyptian Red Sea waters using the bottom trawlers during 2018 fishing season. The mean total length and mean total weight were 17.05± 2.26cm and 64.46± 5.82g, respectively. The length- weight relationship was computed as [$W=.0088L^{3.1475}$].The age of specimens varied from I to IV age groups. The Von Bertalanffy growth parameters were estimated as (L_∞) = 23.04cm and (K) = 0.6 year^{-1} while the average total, natural and fishing mortality coefficients were found as 2.08; 0.81; 1.27 year^{-1}, respectively. The relative yield per recruit and average biomass per recruit were determined as a function of L_C/L_∞ and M/K where it was 0.05 and 0.74, respectively. The exploitation rate (E) was determined using the values of M and F recording 0.61; hence, the stock is considered to be overexploited by the overfishing pressure.

INTRODUCTION

Kerm or Dereny [*Lethrinus variegatus* (valenciennei, 1830)] is the local name in the Egyptian market. *L. variegatus* is known as slender emperor or scavengers belonging to Family Lethrinidae, Order Perciformes. Family Lethrinidae is known as emperors or scavengers; it consists of 5 genera including 41 species and found in sandy and weedy areas in tropical waters **(Berg, 1958; Sabrah, 1998)**. Appearance of *L. variegatus* is correlated to the coral reef mainly in 1.0- 1.5 m depth **(Smith, 1986)**.

L. variegatus is distributed in the indo-west pacific water, in the Red Sea and in East Africa to the Ryukyu Islands, New Caledonia and recently reported from Tonga **(Randall *et al*., 2003)**. Moreover, **Bagnis *et al*. (1984)** reported it from French Polynesian islands. It may be a misidentification of *Lethrinus rubrioperculatus* **(Carpenter & Allen, 1989)**. They are carnivorous bottom feeding mainly on benthic invertebrates or fishes **(Sommer *et al*., 1996)**. Lethrinids have economically and commercially importance because of their preferable taste, highly valued food protein and the high local market price.

Searching in literature revealed that there is no feeding information about *L. variegates* fisheries biology. Consequently, the present study aimed to address the growth, mortality, exploitation rate and the suitable management of *L. variegatus* fishery in the Gulf of Suez in the Egyptian Red Sea.

MATERIALS AND METHODS

A total of 500 specimens of *L. variegatus* (Figure 1) was collected from September 2018 to May 2019, with the help of local fishermen using bottom trawls, operating at Attaka fishing port in the Gulf of Suez (Figure 2).

The total length (TL) and total weight (TW) of each specimen were both measured to the nearest 1.0 cm and 1.0 g, respectively. The pooled data (male and female) were considered. The length-weight relationship (LWR) was estimated by using the power equation of **Pauly (1983)**: $W = aL^b$

Where "W" is the total weight of fish, "L" is the total length, "a" is the intercept, and "b" is the growth type exponent or slope.

Fig. 1. Image of slender emperor *Lethrinus variegatus* (valenciennei, 1830) collected from the Gulf of Suez.

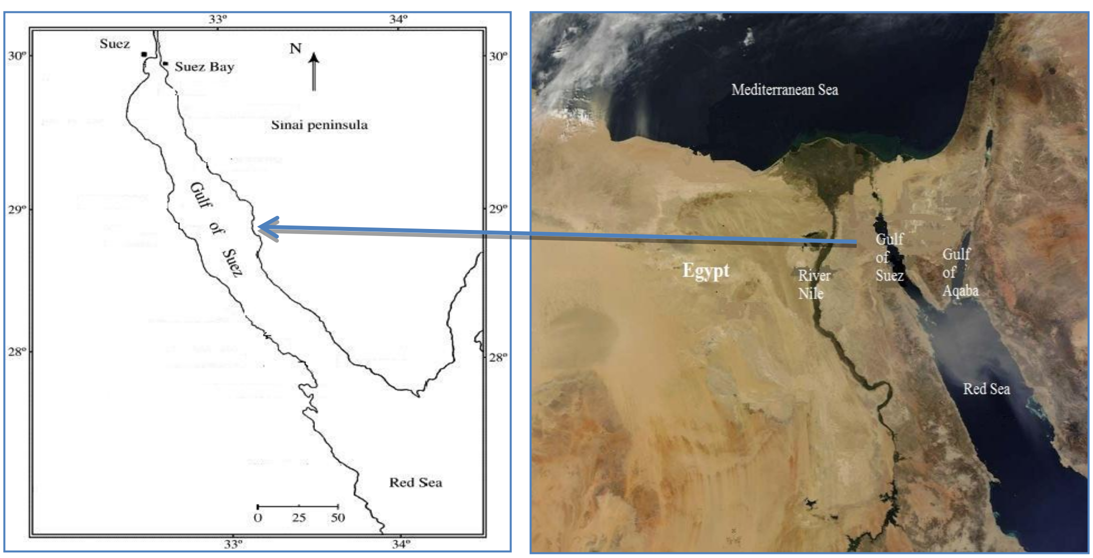

Fig. 2. Sampling area from the Gulf of Suez, Egyptian Red Sea

The growth of *L. varigatus* was estimated using the von Bertalanffy equation for growth **(Haddon, 2011)** as follows:

$$Lt = L_\infty \{1^{-\exp} (-K (t-t_0))\}$$ **(Von Bertalanffy, 1938)**

Where, L_t is the length at the predicted time t, L_∞ is the asymptotic length, K is the growth coefficient and t_0 is the hypothetical age or time where length was equal to zero.

From the values of $L\infty$ and K, the growth curve fitted and the growth performance index (ø) was estimated using the equation:

$$ø' = 2 \log10 L\infty + \log10 K$$ **(Pauly & Munro, 1984)**.

The fish longevity or the maximum age that fish could reach (t_{max}) was obtained according to **Pauly (1983)** and **Taylor (1958)** by the equation:

$$t_{max} = t_o + (3 / K)$$

Survival rate (S), was defined according to (**Ricker, 1975**): "$\mathbf{S = e^{-Z}}$"

The annual mortality (A) is estimated as: A= 1 – S (**Cushing, 1968**)

The annual harvest rate or percentage removal from the fish stock by the trawl fishery was estimated by **Gulland (1983)** equation: Harvest rate = [F/Z (1–e-Z)]*100%

The total mortality (Z) was estimated using four different methods as follows:

a. Converted catch curve method **(Pauly 1983 & Froese, 2006)**

was determined using the equation:

$$Z: Ln (Nt) = Ln (N_0) - Zt$$

Where, Nt is the population size at age t, N_0 is the population size at age 0. Zt is the total mortality at time t.

b. Cumulative catch curve **(Jones & Van Zalinge, 1981)**

which is expressed as follows**:**

$$Ln (CN) = a + (Z/K)*Ln (L\infty - L)$$

Where, CN= cumulative frequency; Z= total mortality rate; K= growth coefficient; 'a' and 'b' = constant.

c. The method of **Beverton and Holt (1956)**

which is expressed as follows**:**

$$Z = K \{(L\infty - \bar{L}_{L'}) / (\bar{L}_{L'} - L')\}$$

Where $\bar{L}$ is the mean length of fish of length L′ and larger; L′ is a length such that all fish of that length and larger are fully selected by the fishery.

d. The method of **Ault and Erhardt (1991)** which is expressed as follows:

$$Z= \{(L_{\infty}- L_{max})/ (\bar{L}- L')\}^{Z/K}$$

Where, L_{∞} is the asymptotic length, K is the growth coefficient, the cut-off length (L'), the mean length ($\bar{L}$) and the maximum length (L_{max}).

The natural mortality (M) was estimated by four methods:

a. The formula of **Rikhter & Efanov (1976)** which is expressed as follows**:**

$$M= \{1.521/t_{mass}.0.72\} - 0.155$$

Where t_{mass}: is the massive maturation.

b. The Empirical equation of **Pauly (1984)** which is expressed as follows**:**

$$\text{Log } M= -0.0066 – 0.2790 \text{ Log } L\infty+ 0.6543 \text{ Log } K + 0.4634 \text{ Log } T$$

Where $L\infty$: is the asymptotic Length, K: Growth coefficient, and T: the average annual sea surface temperature of Gulf of Suez waters. (T = 22.5Co).

c. **Jensen (1996)** which is expressed as follows**:** M = 1.5K

Where K: corresponds to the von- Bertalanffy growth coefficient.

d. Longevity-mortality relationship **(Hewitt & Hoenig, 2005)** which is expressed as follows**:** M = 4.22/t max

Where t: max being the maximum age observed in the sample.

The fishing mortality (F) was estimated by using the following equations:

$$F = Z – M$$

The exploitation ratio (E) was obtained according to **Gulland (1971, 1983)** as:

$$E = F / Z = F / (F + M)$$

According to **Patterson (1992)**, the fishery status was evaluated by matching the current fishing mortality rate with the optimum or the target (F_{opt}) and limit (F_{limit}) biological reference points (BRP) which were delineated as: F_{opt} = 0.5 M and F_{limit}=2/3 M

The probability of length at first capture (L_{c50}) was estimated from the length-converted catch in FiSAT II, in addition to the length at both 25 and 75 captures which corresponded to the cumulative probability at 25% and 75% of the capture, respectively **(Pauly, 1984a).**

Length at first maturity was estimated as:

L_{m50}=2*L∞/3 **(Hoggarth *et al*., 2006; Wehye *et al*., 2017)**

The relative yield per-recruit (Y´/R) was computed using the model of **Beverton and Holt (1964)** as modified by **Pauly and Soriano (1986)** and incorporated in the FiSAT software. The E_{max}, $E_{0.1}$ and $E_{0.5}$ values were computed by using the program, where E_{max} is the maximum sustainable exploitation rate, $E_{0.1}$ is the exploitation rate at which the marginal increases of relative yield/recruit tending to be 10% and $E_{0.5}$ is the exploitation rate under which the stock was reduced to 50% of its unexploited biomass. Relative biomass/recruit (B´/R) was estimated from the successive relationship: B´/R = (Y´/R)/F. In addition, the length structured virtual population analysis (VPA) was conducted after **Sparre and Venema (1992)**.

RESULTS

1. Length-weight relationship (LWR)

From 500 specimens of *L. variegatus*, the total length ranged from 12 to 22.6cm and the total weight was varied from 22.4 to 155.4 g. *L. variegatus* length-weight relationship (Figure 3) was found as: W = 0.0088 × $^{3.1475}$ (r^2 = 0.9674)

2. Age and growth

Four age groups were the result of the otolith reading. The size at the end of each age group was 12.8, 17.9, 19.7, and 21.4 cm for the first, second, third and fourth years, respectively. The growth rate or the increment from the first to the fourth year was 12.8, 5.1, 2.7 and 1.7 cm for the 1st, 2nd, 3rd and 4th age group, respectively. The von-Bertalanffy growth parameters (Fig. 4) of *L. variegatus* were: L∞= 23.04 cm and K= 0.6 year^{-1}.

The growth performance index(ø′) = 2.50 in the pooled sexes (Fig. 5). For the overall growth performance; OGP= 3.86 in the present work, where the derived equation was OGP = log [K (L∞)^3].

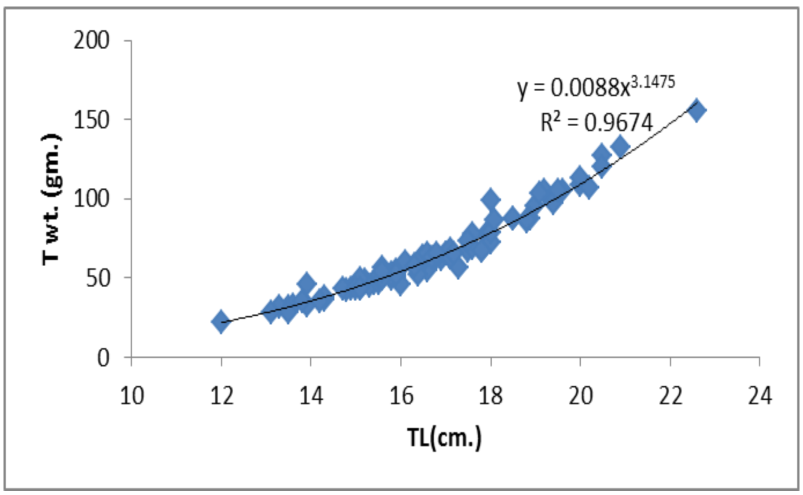

Fig. 3. Length -weight relationship for *L. variegatus* from the Gulf of Suez.

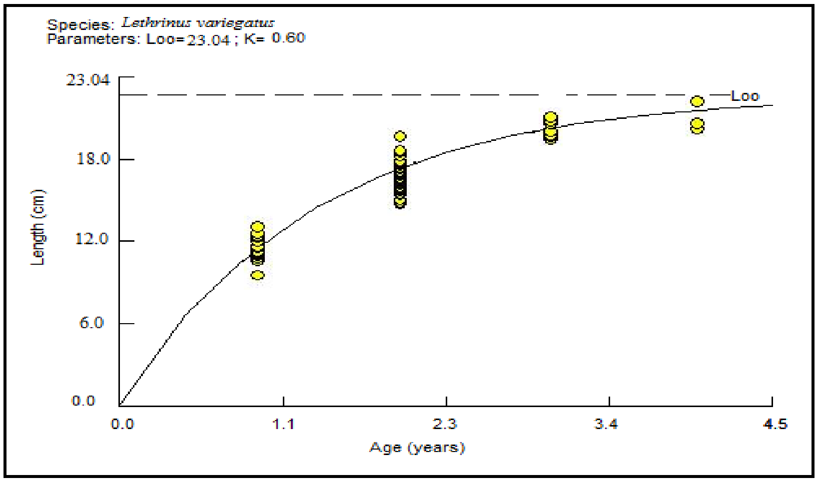

Fig. 4. Von- Bertalanffy growth parameters "L∞& K" estimated by ELEFAN I *L. variegatus* from the Gulf of Suez.

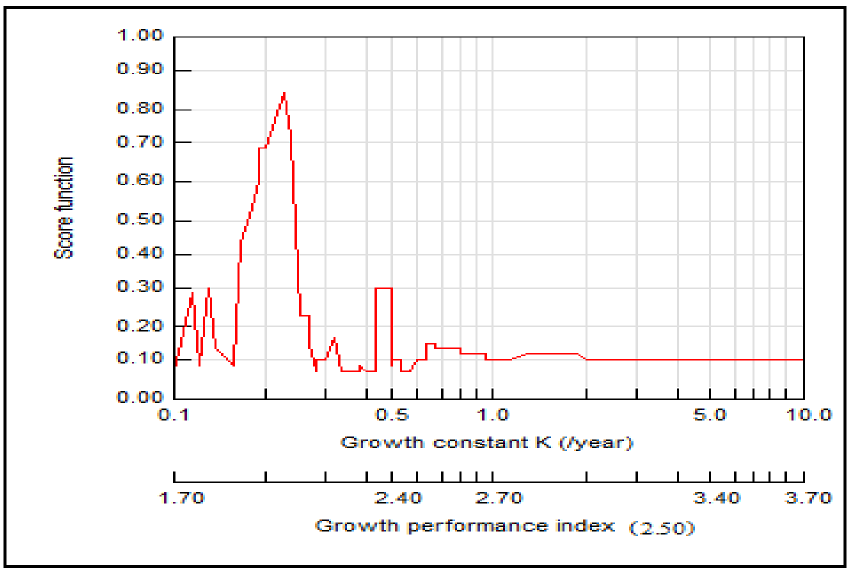

Fig. 5. Estimation K and growth performance index (ø′) for *L. variegatus* from Gulf of Suez.

3. Mortalities coefficients

Mortality rates coefficients (Total and natural mortality) were conducted by several methods as it is the first time to study the population parameters for *L. variegatus* in the Egyptian water in addition to the lack of information to depend on. The values of estimated total mortality rate "Z" and natural mortality rate "M" are represented in Table (1) and (Fig. 6 & 7). The fishing mortality rate "F" was calculated as 1.27 year^{-1}. The exploitation rate (E) was 0.61.

The Survival rate "S" was estimated to be 0.13 year^{-1}; while the annual mortality rate "A" was found to be 0.87 year^{-1} and the annual harvest rate or percentage removal was computed as 53.19% for *L. variegatus*.

The probability of capture of *L. variegatus* was (L_{25}) 12.94cm, L_{50}=13.66 cm and L_{75}=14.39cm (Fig. 8); where the length of the first capture was (L_{c50}) 13.66cm, and the length at first sexual maturity was determined as L_{m50}=15.36cm.

4. Relative yield per recruit (Y/R) and Biomass per recruit (B/R)

The relative yield per recruit was estimated using the knife-edge method and is shown in Fig. (9), the optimum exploitation rates were estimated as; E_{max} = 0.45, $E_{0.1}$ = 0.36 and $E_{0.5}$ =0.30. The relative yield per recruit (Y/R) was determined as a function of L_c/L_∞= 0.05 and M/K= 0.74.

5. Virtual population analysis (VPA)

The length structured virtual population analysis (VPA) of *Lethrinus variegatus* indicated that the high fishing mortality was at 16, 18, 19 and 20 cm length (Fig. 10).

Table 1. Instantaneous total mortality coefficient "Z" and natural mortality coefficient "M" estimated by different methods for *Lethrinus variegatus*.

Total Mortality coefficient Z/ year		Natural Mortality coefficient M/ year	
Methods	**Z**	**Methods**	**M**
Jones and van Zalinge (1981)	4.05	**Rikhter and Efanov's formula (1976)**	0.32
Pauly 1983 and Froese (2006)	2.86	**Pauly's Emprical equation (1984)**	1.24
Beverton and Holt model (1956)	0.71	**Jensen (1996)**	0.90
Ault and Erhardt method(1991)	0.71	**Hewitt and Hoenig (2005)**	0.80
Average value	2.08	**Average value**	0.81

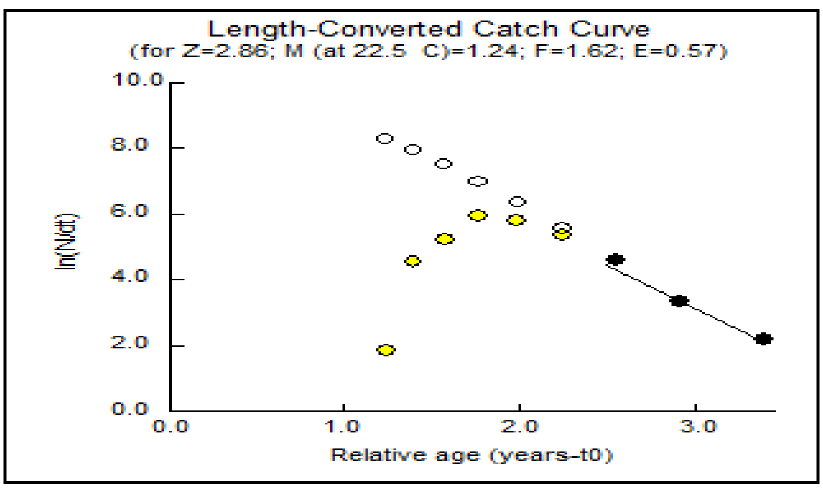

Fig. 6. Length- converted catch curve for *Lethrinus variegatus* collected from the Gulf of Suez "using FiSAT II Program".

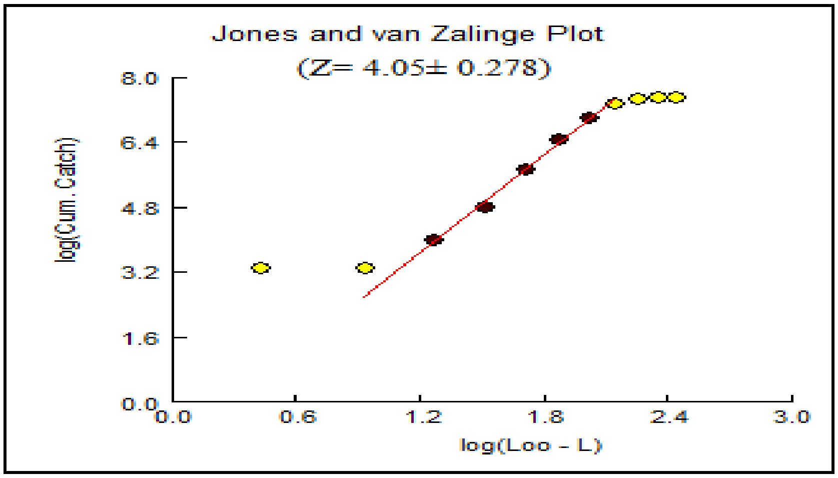

Fig. 7. Cumulative catch curve for *Lethrinus variegatus* collected from the Gulf of Suez "using FiSAT II Program".

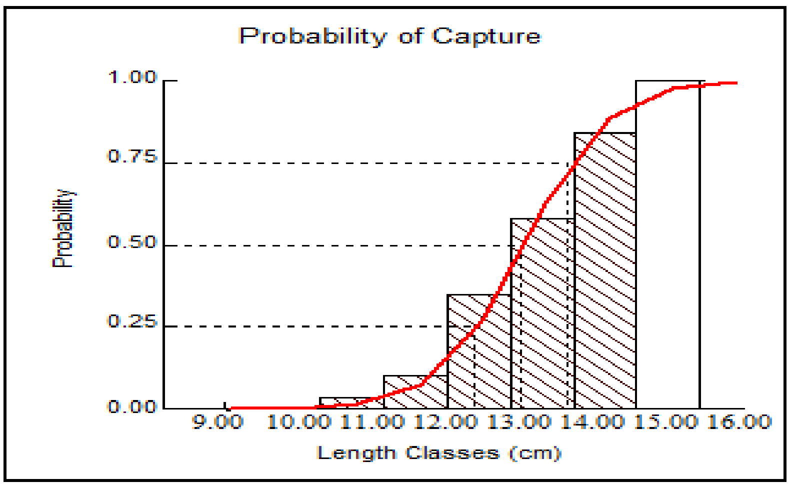

Fig. 8. The probability of capture for *Lethrinus variegatus* collected from the Gulf of Suez "using FiSAT II Program".

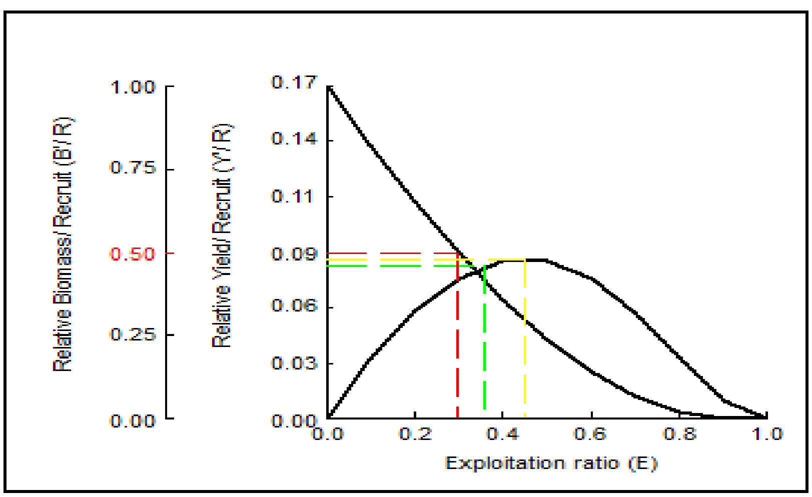

Fig. 9. Relative yield-per-recruit and relative biomass-per recruit of *L. variegatus* from the Gulf of Suez in the Red Sea, Egypt.

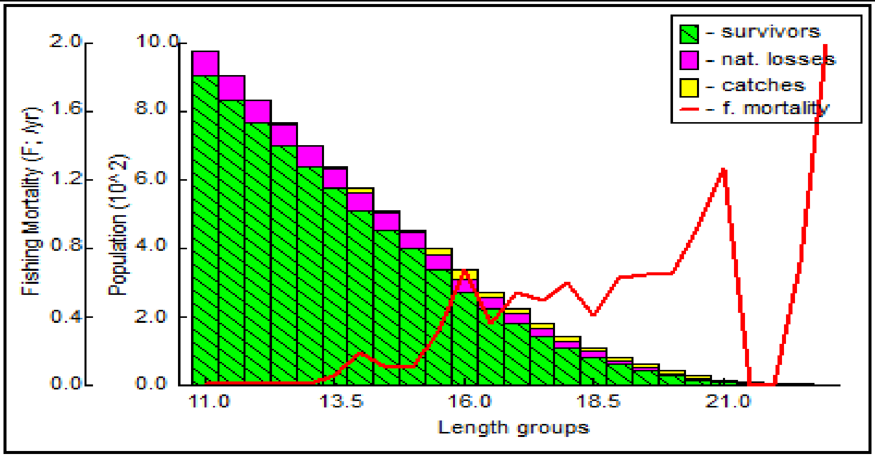

Fig. 10. Length-structured virtual population analysis of *L. variegatus* from the Gulf of Suez

DISCUSSION

Length-weight relationship (LWR) considered as an important indicator for the environment stability and has a vital role in the fishery management (**Richter *et al*., 2000; Baset *et al*., 2020**). Length-weight relationship (LWR) of *L. variegatus* was found as W = 0.0088 × $^{3.1475}$ (r^2 = 0.9674); "b" was nearly "3" indicating positive allometric growth, as the fish growth in weight is higher than its growth in length. According to **Snedecor (1956)**, the constant "b" is the coefficient of the growth type, "b" value usually between 2 to 4, but when the value is close to 3, this mean that the growth is isometric and the fish grows in length and weight at the same rate, while if b < 3 indicates a negative allometric growth, this means that the fish grows in length more than its growth in weight. In case of b > 3, a positive allometric growth isindicated and the fish grows in weight higher than its growth in length. It counts to know that the value of (b) varies and affected by many factors as sampling area, or sample size, as well as the difference in the seasonal environmental conditions (**Le Cren 1951; Weatherley 7 Gill 1987**).

A lot of mathematical functions were used to describe the growth in fishes. The von- Bertalanffy growth function (VBGF) was the most frequently one, it is also used in other marine organisms where the constants could be estimated into early stock assessment models. The growth was considered as a balance between anabolic and catabolic processes in an organism , and hence, the function was obtained (**von Bertalanffy, 1938, 1957; Pauly, 1980**). The von Bertalanffy growth parameters are important tools to depict the life histories of fish, such as age and size at maturity. For example; high growth rate coefficient "K" is associated with young age and small size at maturity, high reproductive output, short life span and small asymptotic length (L_∞). Conversely, species with low "K" are older in age and bigger in size at maturity, lower reproductive output, longer life spans and large asymptotic length (**Jennings *et al*., 2001**). The differences in the ecological conditions and environmental factors as temperature and food availability could cause a variation in the growth parameters (**Goncalves *et al*. 2003**). **Saetre *et al*. (2002)** and **Cicek and Avsar (2011)** recorded the fluctuation in the growth from year to year due to the variability in the fish biological characteristics. In the present case, four age groups were recorded (12.8, 17.9, 19.7, and 21.4cm), *L. variegatus* was found to have high growth rate and short life span; additionally, von- Bertalanffy growth parameters were [$L\infty$= 23.04 cm and K= 0.6].

The composite indices is suitable for the overall growth performance (OGP) for inter- and intra-specific comparisons, where it is difficult to compare in the non-linear growth functions **(Pauly, 1979; Munro & Pauly, 1983; Froese, 2006; Tenjing, 2020)**. It was noticed that, the overall growth performance (OGP) in the present work was 3.86.

Data revealed that the lifespan of this species reached approximately 4 years; while in France it was found that the maximum reported lifespan was 15 years (**Loubens, 1980**).

The total mortality rate "Z" and natural mortality rate "M" of *L. variegatus* were 2.08 $year^{-1}$& 0.81 $year^{-1}$, respectively; while the fishing mortality rate "F" was 1.27 $year^{-1}$. The fishing mortality rate "F" was more than the biological reference points calculated by the equation of **Patterson (1992)** where, F_{opt} = 0.41 and F_{limit} = 0.54. The exploitation rate (E) for *L. variegatus* in the present study was 0.61, and F> M by 36%, so the fishing mortality should be reduced, while the sustainable optimum yield is obtained when F= M and E value = 0.5 as assumed by **Gulland (1971)**. In addition, the Z/K ratio was 3.47 which is more than ≈2 according to **Etim *et al*. (1999)**. Therefore, the *L. variegatus* fishery was found to be under over exploitation. The over exploitation may be related to the overfished stocks.

The *Lethrinus variegatus* survival rate "S" and the annual mortality rate "A" were found to be 0.13 $year^{-1}$& 0.87 $year^{-1}$, respectively. While the annual harvest rate was 53.19%.

The probability of capture of *L. variegatus* (L_{25}) was12.94 cm, L_{50}=13.66 cm and L_{75}=14.39cm; where the length at first capture (L_{c50}) was 13.66cm, which is considered to be higher than the estimated length at first sexual maturity (L_{m50}=15.36cm). The length at first capture and length at first maturity are indicators and are important tools for the management of a target fishery, because they are used to determine the minimum allowed mesh size in the fishing area. In the present study, the length at first capture was lower than length at first maturity, which indicates that the stock of *L. variegatus* was harvested before reaching maturity, and gives at least one generation to the fishery **(Marcus, 1989; Wehye *et al*., 2017)**. This would confirm that the catch is mainly composed of small fish and exposed to overfishing **(Pauly & Soriano, 1986).**

The relative yield per recruit was estimated using the knife-edge method and the optimum exploitation rates were estimated as; E_{max} = 0.45, $E_{0.1}$ = 0.36 and $E_{0.5}$ =0.30, where the fishery exploitation rate must not exceed the E_{max} and $E_{0.5}$ to ensure the sustainability of that fishery. In the current work, the computed exploitation ratio was 0.61, which is higher than the $E_{0.5}$= 0.30 and E_{max}= 0.45, that clearly clarifies the overfishing pressure on *L. variegatus* fishery. The relative yield per recruit (Y/R) was determined as a function of L_c/L_∞= 0.05 and M/K= 0.74, that reflects various results equal to the changes in the mesh size.

According to the length structured virtual population analysis (VPA) of *Lethrinus variegatus*, the high fishing mortality was displayed at 16, 18, 19 and 20 cm length, this would indicate that the large individuals were going under fishing stress, which may affect the new recruit in the following fishing season.

CONCLUSION

Appropriate rules must be enforced to minimize the pressure on the *L. variegatus* fishery by preventing the use of illegal fishing gears and unsuitable nets mesh sizes.

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