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Age and growth, mortality and exploitation ratio of *Epinephelus summana* (Forsskål, 1775) and *Cephalopholis argus* (Schneider, 1801) from the Egyptian Red Sea coast, Hurghada fishing area

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ABSTRACT

The age and growth of two grouper fish species, *Epinephelus summana* (Forsskål, 1775) and *Cephalopholis argus* (Schneider, 1801) from Egyptian Red Sea off Hurghada, were studied based on the otolith readings. The maximum longevity of the two species was 10 and 6 years for *E. summana* and *C. argus* respectively. The age group II was the most dominant age group in the catch forming 46.09 % for *E. summana* and 22.33% for *C. argus* from the total collected samples. The asymptotic standard length ($L\infty$) and the growth coefficient (K) were estimated as 63.39 cm and 0.13 year^{-1} for *E. summana* and 44.22 cm; and 0.26 year^{-1} and *C. argus*, respectively. The total mortality was computed as 0.82 and 1.31 year^{-1} for *E. summana* and *C. argus*, respectively. The mean values of natural mortality were 0.33 and 0.56 year^{-1} for *E. summana* and *C. argus*, respectively. Accordingly, the fishing mortality rates were estimated as 0.49 and 0.75 year^{-1} for *E. summana* and *C. argus*, respectively. The exploitation rates of *E. summana* (0.6) and *C. argus* (0.57) along with the fishing mortality rates reflect the overexploitation situation of the two serranid species in the Egyptian Red Sea.

INTRODUCTION

Fishes belonging to the family Serraniade consider as one of the most commercially important fishes in the Red Sea. Family Serranidae which are commonly known as groupers, rockcods, hinds, and seabasses contains more than 400 species which are widely distributed in tropical and subtropical areas allover the world. This family comprises from a large number of species, at least 31 are found in the Red Sea (Randall, 1983). They found in both Mediterranean and Red Seas but most common and diverse in the Red Sea. The serranid subfamily Epinephelinae comprises about 159 species in 15 genera. The genus *Epinephelus* comprises 98 species from which 16 species were found in the Red Sea While, the genus *Cephalopholis* comprises 22 species from which 17 species were recorded in the Red Sea and Indo-Pacific region (Heemstra and Randall, 1993).

Serranids are generally commonly known as groupers, rockcods, hinds, (Heemstra and Randall, 1993). The groupers are one of the main components of the artisanal fisheries and usually have high prices in national and international markets. In the Egyptian Red Sea, groupers are exploited by the artisanal fishery and contributed about 30% of the total fish landings of the artisanal fishery (Mehanna, 2005).

Cephalopholis argus (Schneider, 1801), also known as roi, bluespotted grouper, and celestial grouper (Fig. 1A), is extremely widely distributed, occurring in warm waters from the Red Sea to South Africa and east to French Polynesia and the Pitcairn group. It is also present in northern Australia, Lord Howe Island, and Japan, and has been introduced to the Hawaiian Islands. It makes use of a variety of habitats but prefers the exposed fronts of reefs, at depths of up to 40 m (Liu & Choat, 2008).

Epinephelus summana (Forsskål, 1775), also known as summana grouper (Fig. 1B) is a reef-associated species that occurs in shallow protected coral reefs and in shallow lagoons and seaward reef slopes (1 to 30 m) or brackish-water environments (Samoilys, 2018). It distributes in Western Indian Ocean, known only from the Red Sea and Gulf of Aden and reported from Somalia and Socotra (Yemen) (Heemstra and Randall, 1993). There are very few studies on its biology are available.

Although variety of studies have been done on the family Serranidae in the Egyptian waters, however there is insufficient studies about the biology, dynamics, species discrimination and fisheries status, particularly in Hurghada fishing area, Red sea, Egypt. Therefore, the current work was suggested to fill such gab of the biological and dynamical data. It will provide information on age, growth, length-weight relationship and mortality of two grouper species in the Red Sea for further stock assessment studies.

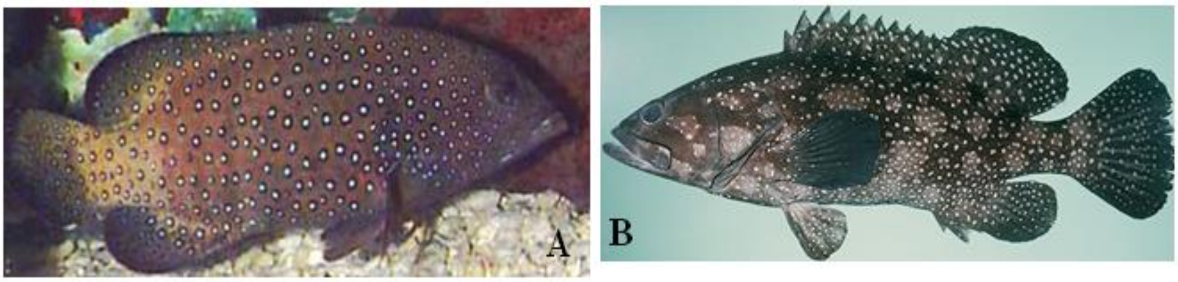

Fig. 1: *Cephalopholis argus* (A) and *Epinephelus summana* (B)

MATERIALS AND METHODS

Study area and samples collection

Hurghada fishing area is at the northern part of the proper Red Sea coast between latitudes 27°10′N–27°30′N and longitudes 33°70′E–33°85′E. Monthly random samples of serranid species were collected from the landing site at Hurghada city. The grouper samples were identified by species and these measurements for each specimen were taken: total length "TL" to the nearest 0.1 cm, standard length (SL) to the nearest 0.1 cm, total weight "W" to the nearest 0.01 g and sex was detected.

Length-weight relationship

The relationship between standard length SL (cm) and body weight W (g) of serranid specimens was expressed by the following equation (Froese, 2006): $W = a\ L^b$

Where a and b are constants whose values were estimated by the least square method.

Age determination

The sagittal otoliths were used for age determination of serranid species. The extracted otoliths were washed with distilled water and stored dry in envelops with full information for further examination. The distance from the focus to each annulus and the total otolith radius were measured. The relationship between total length and otolith radius (from otolith focus to the margin) was calculated for all fishes according to Whitney and Cohen (1956), as follows: $L = a + b R$

Where L is total or standard length of fish in cm; R is the otolith radius in mm; a and b the constant representing the intercept and the slope of the straight line respectively.

Back-calculated length at the end of each year of life was determined using the Fraser-Lee (Duncan, 1980) method following Campana and Casselman (1993) as follows:

$L_i = a + (R_n/R) \times (Lc - a)$

Where L_i is the back calculated length at annulus i, L_c is the length at capture, R_n is the otolith radius corresponding to n^{th} year, R is the otolith radius at the time of capture.

Length-based Growth Performance Index (Ø')

Growth performance index was computed to compare the von Bertalanffy growth model of fish with other fish species according to the following formula (Pauly & Munro, 1984): $Ø' = \text{Log } K + 2\text{Log } L_\infty$

Where Ø′ = Phi-prime.

Mortality rates and Exploitation Ratio:

The three types of mortality coefficients; Total (Z), natural (M) and fishing (F) mortality were estimated. "**Z**" was computed using the methods of Jones and Van Zalinge (1981) and Pauly (1983). "**M**" was computed using Taylor (1960), Rikhter and Efanov‟s (1976) as well as Pauly (1980) methods. "**F**" was calculated from the equation: **F = Z - M**. The exploitation ratio "**E**" was estimated using the equation **E = F / Z** (Gulland, 1971).

RESULTS AND DISCUSSION

Length frequency distribution

The analysis of length-frequency data can be used for the estimation of age, growth, survival, mortality rates and analytical yield models such as the yield per recruit (Beverton and Holt, 1966; Gulland ,1971; Pauly, 1984; Mehanna *et al.*, 2018). It was found that, there is a great variability in length distribution pattern of the two grouper species. Length frequency distribution of both *E. summana* and *C. argus* is represented in Fig. 2. For *E. summana*, the length ranged between 16 to 51 cm SL (from 20 to 60 cm TL) and the length groups 23, 24, 25and 26 cm SL are the most frequent groups in the catch while the groups (16 and from 46 to 51 cm SL) were the least frequent ones. On the other hand, the length of *C. argus* ranged between 17 and 38.7 cm SL (from 21 to 46.5 cm TL) and the highest frequency was found at length group 24 and 27 cm.

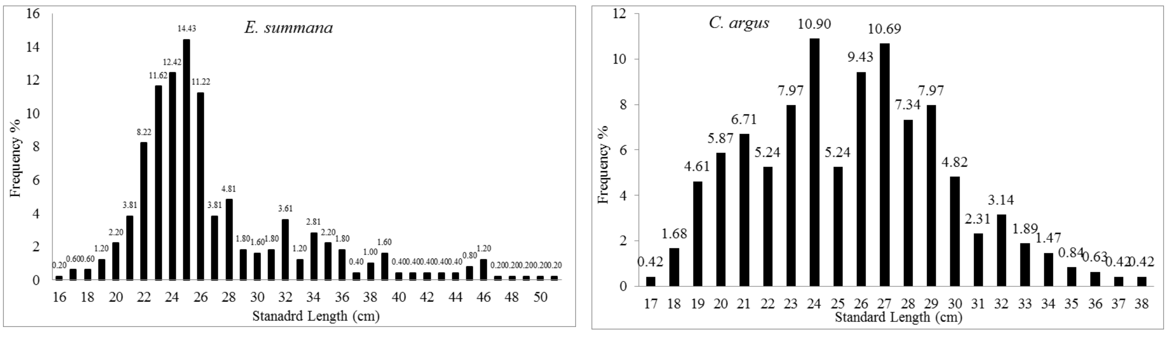

Fig. 2: Length frequency distribution of the two grouper species from Re Sea.

Total length-Standard length relationship

The standard - total length relationship of the two grouper species studied was found to be linear (Fig. 3) and represented by the following equations:

E. summana	TL= 1.135 SL+1.7085	R^2= 0.9805
C. argus	TL= 1.1594 SL + 0.7881	R^2= 0.9754

The high values of regression coefficient (R^2) indicate that the correlation of total length and standard length is best described by linear regression equations.

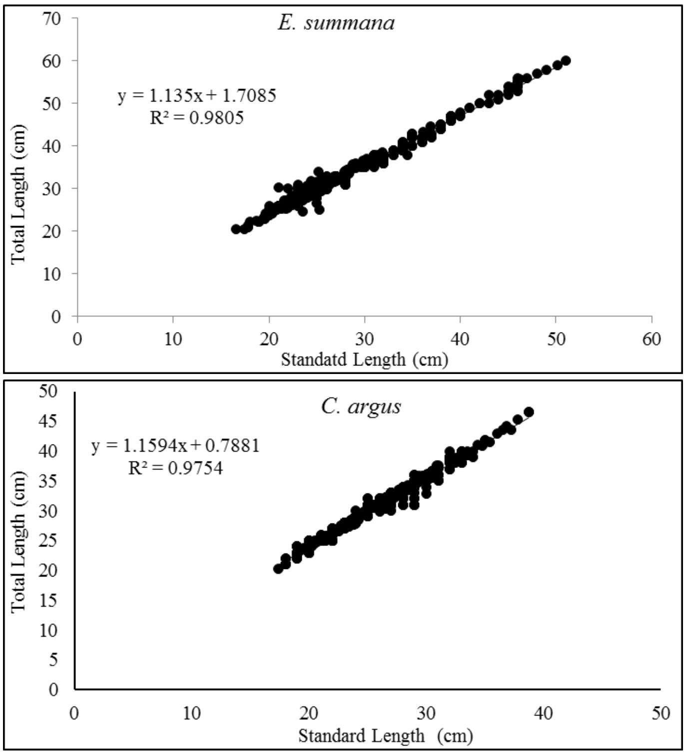

Fig. 3: Total-Standard length relationship of the two grouper species from Red Sea.

Standard Length-Weight relationship

The length-weight relationship has its important applications in the field of the fisheries management. Le Cren, (1951) and Lagler, (1956) discussed the uses of this relation and concluded that, it used to calculate the length or the weight of fish when one or the other is known. This relationship is also used to measure the variation from the expected weight for a length of individual fish as an indication of fatness or gonad development and estimate the total yield of fish caught when length and number of fish are known. The relationship between length and weight may be assigned to factors like food accessibility and feeding rates (Bagenal and Tesch, 1978), the spawning season (Mahé *et al.*, 2017), the size composition of the individuals sampled and the time of collecting specimens (Petrakis & Stergiou, 1995; Moutopoulos & Stergiou 2002; Mehanna & Al-Mamry, 2012).

The length - weight relationship for the two serranid species under study (Fig. 4), is expressed by the following equations:

E. summana	$W= 0.0218\ SL^{3.057}$	R^2= 0.979
C. argus	$W= 0.0232\ SL^{3.0382}$	R^2= 0.9326

The growth in weight relative to fish size in *E. summana* and C. *argus* was isometric; where the b-value statistically not differ from 3 (b= 3.057 with CI:

3.0145- 3.0931for *E. summana* and b= 3.038 with CI: 2.96 - 3.11for *C. argus*). Also, the b-value and the type of growth from this study was coincide with that of the previous ones (Table 1).

Le Cren (1951) stated that, length-weight relationship of most fishes can be described by the following power formula: $W=a*L^b$ and the power (b) ranges between 1.34 and 3.68 for the different fish stocks (Hile, 1936).

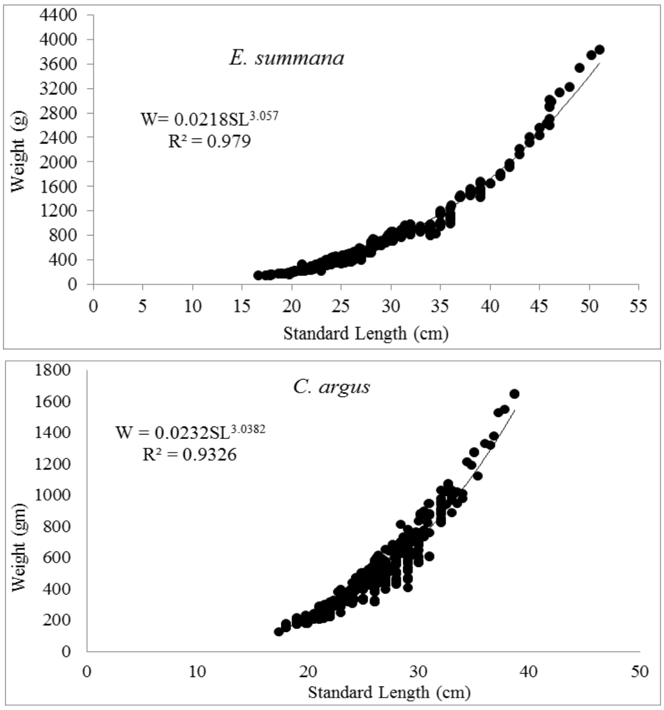

Fig. 4: Length - weight relationship for the two grouper species from Red Sea

Table 1: The length weight parameters compared with previous studies

	Location	Length type	a	b	Growth type*	Authors
E. summana	Egypt	TL	0.015	3.00	I	Pauly, *et al.* (1998)
	Egypt	SL	0.026	3.00		
	Egypt	--	0.0001	3.07	I	Osman (2000)
	Egypt	SL	0.022	3.06	I	Present study
C. argus	Egypt	--	0.021	3.02	I	Mohammad (2007)
	Egypt	SL	0.023	3.038	I	Present study

*I means isometric growth

Age determination

In the present study, sagittal otoliths of the two grouper species were used for age determination. The shape of the otolith is oval with irregular margins with the number of annuli, and each annulus consists of one opaque and one translucent zone.

The examination of the grouper otoliths has some difficulties in the age interpretation. Accessory marks (false ring) are usually found in the central zone of the otolith within the first annual growth ring. This accessory mark was observed on the otolith of all examined fishes. By back calculations, it was possible to determine the length of the fish at the time of formation of that mark. This calculated length is nearly equal to the length at which the fish changes its habitat from the pelagic to the demersal life in coastal waters. So, this first accessory mark can be regarded as the larval ring. The examined otoliths revealed that the maximum life span for the grouper species was ten years for *E. summana* and six years for *C. argus*.

Age composition

The age composition (Fig. 5) of *E. summana* revealed that this species attained 10 age groups from 1 to 10 years old, while the age composition of *C. argus* was 6 age groups from 1 to 6 years old. The most dominant age group in the catch was the second age group for both *E. summana* and *C. argus* forming 46.09 % and 22.33% of the total catch for the two species respectively.

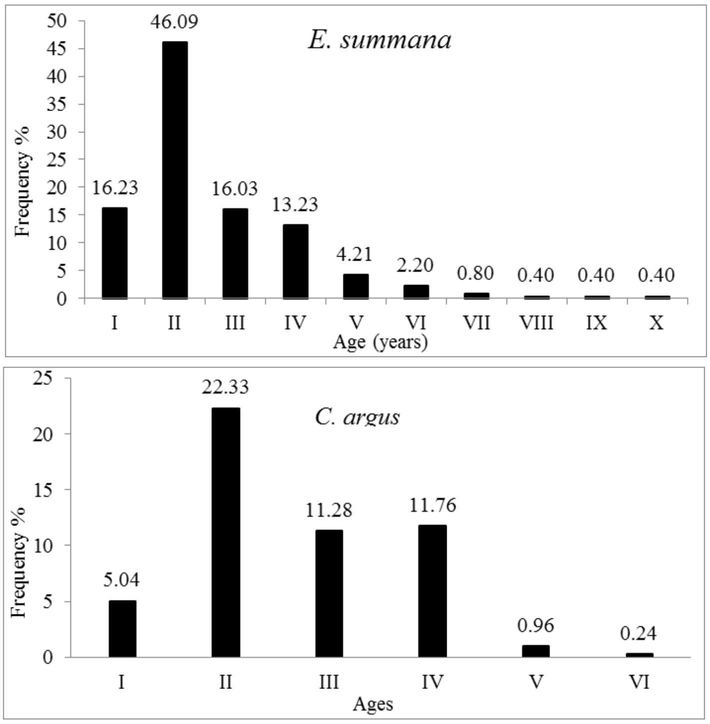

Fig. 5: Age composition for the two grouper species, *E. summana* and *C. argus* from Red Sea

Back calculations and growth in length

The relationship between SL and otolith radius (S) was found to be linear and was best described by the following equations:

E. summana SL= 5.303R + 1.405 R^2= 0.855

C. argus SL = 6.174R + 1.409 R^2= 0.874

Accordingly, the equations used in back calculation were found to be as follows:

E. summana $SL_n = 1.405 + (S_n/S)*(SL -1.405)$

C. argus $SL_n = 1.409 + (S_n/S)*(SL – 1.409)$

The back calculated lengths at the end of each year of life as well as the annual increment (Fig. 6) for the two grouper species cleared that the growth in length was the maximum by the end of the first year of life. The *E. summana*, and *C. argus* attained lengths of 20.03 and 20.20 cm SL, respectively, after that a gradual decrease in the annual increments with further increase in age was observed. Similar trends in length increment have been recorded for all fish species studied in the Egyptian Red Sea (e.g.: Mehanna, 2005 and Mohammad, 2007 on serranid species; (Mehanna, 2011 and Mehanna *et al.,* 2017 on lethrinid species; El-Mahdy, 2018 on sparid species; Ahmed, 2018 on mullid fishes; Mehanna *et al.,* 2018 on siganid species).

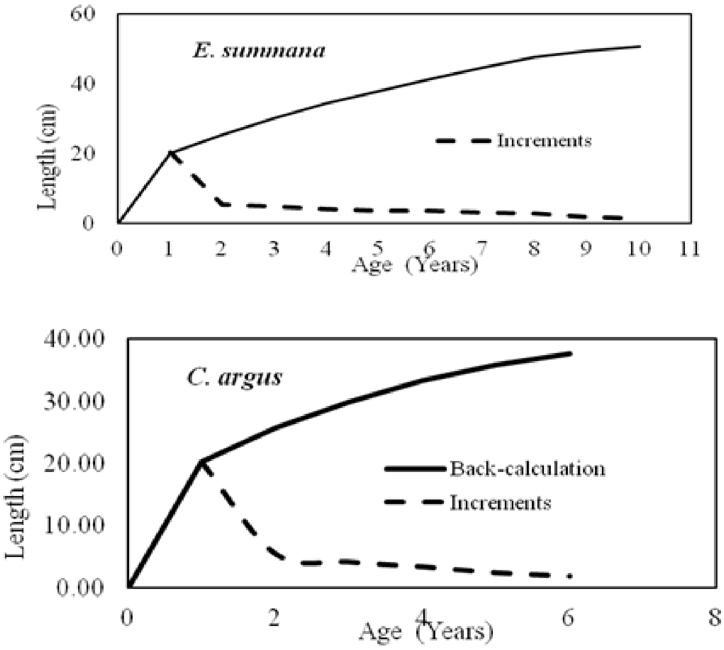

Fig. 6: Growth in length and its increment of the two grouper species from Red Sea.

Von Bertalanffy growth model

Growth parameters of the von Bertalanffy growth model (L_∞, K and t_o) are the basic input data into various models used for managing and evaluate the status of the exploited fish stocks, these parameters facilitate the comparison between the growth of fishes belonging to different species or to the same species at different times and different localities (Mehanna, 1996).

The values of von Bertalanffy constant "$SL\infty$" were 63.39 and 44.22 cm for *E. summana* and *C. argus,* respectively. While, the obtained values of "K" were 0.13 and 0.26 year^{-1} for *E. summana,* and *C. argus*, respectively showing a relatively high value of growth coefficient "K" for *C. argus* which means that this species reaches its asymptotic length faster. The values of "t_0"estimated from von Bertalanffy plot were -1.70 and -1.33 year for *E. summana,* and *C. argus* respectively.

The von Bertalanffy growth in length equations for serranid species studied are as follows:

E. summana $SL_t = 63.39\ [1 - e^{-0.13\ (t + 1.70)}]$

C. argus $SL_t = 44.22\ [1 - e^{-0.26\ (t + 1.33)}]$

The values of $W\infty$ for the two grouper species were obtained by applying the length weight relationship by using the value of $SL\infty$ and were found to be 7034.42 and 2211.42 for *E. summana*, and *C. argus* respectively . Accordingly, the von Bertalanffy growth formula for growth in weight, are as follows:

E. summana $W_t = 7034.42\ [1- e^{-0.13\ (t + 1.70)}]^{3.057}$

C. argus $W_t = 2318.87\ [1 - e^{-0.26\ (t + 1.33)}]^{3.0382}$

The estimated growth parameters in the present work for the two grouper species (Table 2) along with those available from previous studies showed a difference between these values for *C. argus*. This variation between results may be due to different localities, methods used, environmental condition, fish maximum length and number of samples.

Growth performance Index (Ø')

The growth performance values in length (Φ_L) were 2.73, and 2.71 for *E. summana,* and *C. argus* respectively. The growth performance values in weight (Φ_w) were 1.69, and 1.66 for *E. summana,* and *C. argus* respectively.

Growth performance index (Ø) was used to compare the growth rate of fish species in different localities or/and with other species in the same area (Pauly and Munro, 1984). In the present work the growth performance index (Ø) results of *C. argus* was lower than that obtained by Mohammad (2007), where the values 2.93. This may be attributed to the fact that the environmental conditions were better in this period (2007) than now.

Table 2: Von Bertalanffy growth parameters compared with previous studies

Species	Location	L_{max} (cm)	L_∞ (cm)	W_∞ (g)	K (yr^{-1})	t_0 (yrs.)	Ø	Author
E. summana		51	63.39	7034.42	0.13	-1.70	2.73	Present study
C. argus	South Africa		62.2		0.19	-0.73		Heemstra and Randall (1993)
	Red Sea, Egypt	38.7	52.6		0.164	-1.41	2.93	Mohammad (2007)
	Red Sea, Egypt	38.7	44.22	2318.87	0.26	1.33	2.71	Present study

Mortality and survival rates

The total mortality coefficient (Z) is composed of two components namely fishing mortality (F) which caused by man and natural mortality (M) which caused by all other causes other than fishing; such as predation, ecological conditions and diseases.

The total mortality coefficient "Z" for *E. summana*, and *C. argus* was estimated by Jones and Van Zalinge (1981) and the length converted catch curve of Pauly (1983) (Fig. 7). The obtained values from these methods were very close to each other for the two species. The mean total mortality value was 0.82 and 1.31 for *E. summana* and *C. argus*, respectively. It is clear that the total mortality rate of *C. argus* is higher than that of *E. summana*.

The mean values of natural mortality coefficient "M" for *E. summana* and *C. argus* estimated from the three different methods were 0.33 and 0.56 $year^{-1}$, respectively. Accordingly, the calculated values of fishing mortality were F = 0.49 for *E. summana* and F = 0.75 for *C. argus.*

The high values of fishing mortalities reflected the over-fishing condition for grouper fish stock in Hurghada. It is also clear that *C. argus* were characterized by higher rate of total and fishing mortality than *E. summana*. On the other hand, the mortality of *C. argus* was less than that determined by Mohamed (2007), who gave Z=1.88 $year^{-1}$, M=0.44 $year^{-1}$ and F=1.44 $year^{-1}$,

Ricker (1975) defines the survival rate (S) as the number of fish alive after a specified time interval, divided by the initial number, usually on a yearly basis. In the present study, the survival rate was found to be 0.44 and 0.27 $year^{-1}$ for *E. summana* and *C. argus,* respectively. The low values of survival rate confirmed the critical situation of the present investigated stocks.

Exploitation Ratio (E)

The exploitation ratio is very important to estimate the state of the stock if optimum, underexploited or overexploited. The values of exploitation rate for *E. summana* and *C. argus* were 0.60 and 0.57, respectively which is high and exceeds the optimum one (E = 0.5) given by Gulland (1971). He mentioned that the optimum exploitation rate for any exploited fish stock is about 0.5 at $F_{opt.} = M$. So, these high values indicating that the stock of grouper species in Hurghada is overexploited. This finding is agreed with that of Mohamed (2007) who estimated the E-value at 0.77.

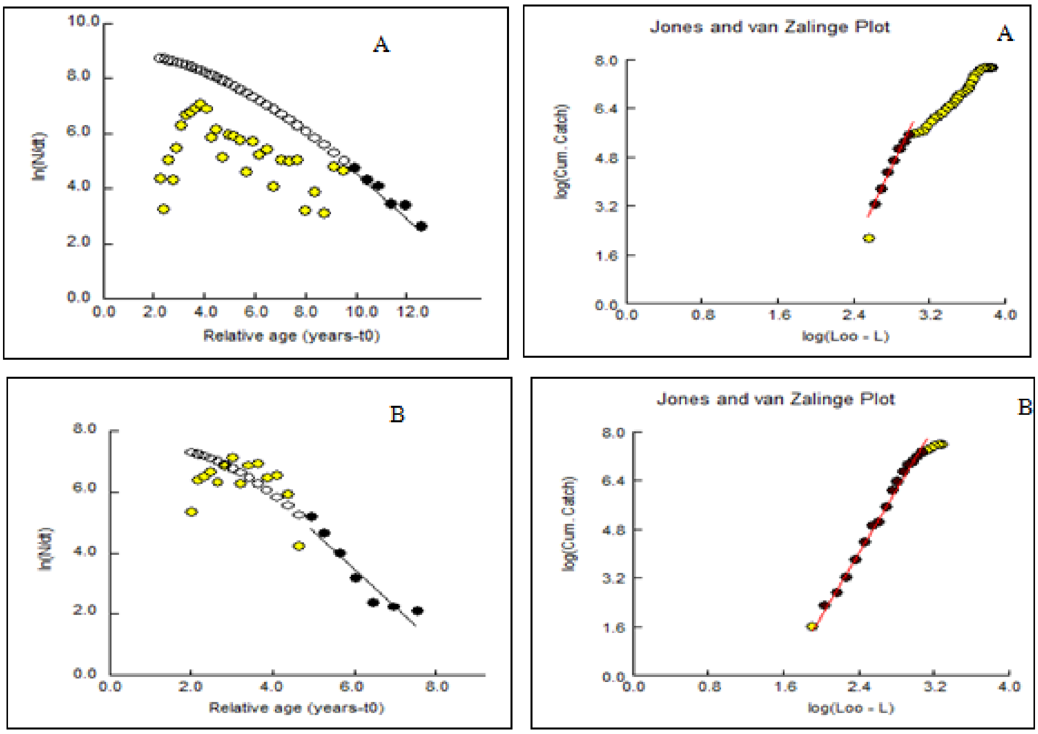

Fig. 7: Jones & Van Zalinge plot and Length converted catch curve of *E. summana* (A) and *C. argus* (B) from Red Sea

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