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Basic life-history parameters of the blue swimmer crab *Portunus pelagicus* (Linnaeus, 1758) along the Gulf of Suez, Red Sea, Egypt

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ABSTRACT

The resource managers need to know life-history parameters to understand the biology and population dynamics of the respective species and respond to risks to natural populations and ecosystems. Sixteen life-history traits of the blue swimmer crab *Portunus pelagicus* along the Gulf of Suez were assigned. *P. pelagicus* is one of the popular shellfish species that stands out for its higher commercial value and consumer preference. The study revealed that *P. pelagicus* has t_{max} equals 3 yrs for males and 2 yrs for females. The overall sex ratio (♂**:**♀) was 1:0.78. The results do not reject the null hypothesis H_o of a 1:1 ratio of male to female. The average fecundity increased with increasing the CW where it was 407338 (±35529), 617937 (±42086), and 793928 (±37610) eggs per batch for a mean CW of 10.7, 14.6, and 18.1 cm respectively. The estimated CW-Weight equations were $W= 0.0175\ CW^{3.277}$ ($R^2 = 0.94$), $W= 0.0242\ CW^{3.273}$ ($R^2 = 0.93$), and $W= 0.0171 CW^{3.276}$ ($R^2 = 0.94$) for males, females, and combined sexes respectively. The value of *b* indicated a positive allometric growth (*b* > 3) for both sexes. The average values of CW_∞, K, t_o and W∞ as well as the computed Ø' values were 23.83 cm, 0.78 yr^{-1}, 0.27 yr, 570.0 g, 2.65 for males, 20.44 cm, 0.93 yr^{-1}, 0.01 yr, 471.0 g, 2.59 for females, and 23.86 cm, 0.89yr^{-1}, 0.02 yr, 557.0 g, 2.70) for combined sexes respectively. The mortality rates were estimated as: Z was 2.44, 3.41, and 2.89 /yr, M was 0.90, 1.17, and 1.09/ yr, F was 1.54, 2.24, and 1.80 /yr), and the estimated E was 0.63, 0.66, and 0.62 for males, females, and combined sexes respectively. Based on these results, a sustainable management program for *P. pelagicus* in the Gulf of Suez could be proposed.

INTRODUCTION

Life history characteristics such as the population size, density, sex ratio, the timing of reproduction, longevity, age and size at maturity, reproductive potential, growth pattern and rate, and mortality rate greatly differ among different animal species. In fishes, these characteristics are important to determine sustainable harvest rates, estimate harvest

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rates from changes in average length, and project the likely impact of different management actions. These parameters are probably most important for governing community change and play an important role in understanding and managing populations and ecosystems. About 7000 fish species are used by humans for food, sports, or in the aquarium trade. However, basic life history parameters which are important for management, are known for less than 2000 species (**Froese and Pauly, 2000; Thorson *et al*., 2017; Brown and Choe, 2019**).

The blue swimmer crab *Portunus pelagicus* (Linnaeus, 1758) is a crustacean belonging to infraorder Brachyura "true crabs", Family: Portunidae "swimming crabs". It is known by many other different common names such as blue crab, blue manna crab, flower crab, and a sand crab. Also, it has different synonyms: *Cancer pelagicus* (Linnaeus, 1766), *Neptunus pelagicus* (De Haan, 1833), and *Lupea pelagica* (Milne-Edwards, 1834). It is easily recognized by its distinctive shape and color; the carapace is hard, rough, and broadly flattened, extending to nine protrusions on each side, with the last one quite pronounced. It has one pair of large front pincers, with three pairs of long ridged walking legs and a pair of modified legs as swimming paddles. Its colors vary from dark brown, blue, and purple with pale mottling (**Stephenson, 1972; Kangas, 2000; Jones and Morgan, 2002; Ruppert *et al.*, 2004; Ng *et al*., 2008; Lai *et al*., 2010; Abdul-Sahib, 2012**). The blue swimmer crab *P. pelagicus* is widely distributed in nearshore marine and estuarine waters throughout the Indo-West Pacific. It is also found as a Lessepsian migrant in the eastern Mediterranean Sea. It lives in a wide range of inshore and continental shelf areas, including sandy, muddy or algal, and seagrass habitats, from the intertidal zone to at least 50 m depth (**Kangas, 2000; Galil, 2007; Liu, 2008; Eleserio and Mandreza, 2010; Occhipinti-Ambrogi *et al*., 2010)**.

The blue swimmer crab *P. pelagicus* is one of the living aquatic resources, which have high demand and high value in the local, and world markets. It is a large-sized crab, a commercially important, highly prized species, and highly regarded for its taste. It is targeted and caught for food using a variety of fishing gears; mainly by crab traps, gill nets, trammel nets, drop nets, handpicking, or retained trawl nets. The females are generally sold at higher prices than the males (**Jones and Morgan, 2002; Chande and Mgaya, 2003; Efrizal *et al.*, 2015; Muchtar, 2016**). The blue swimmer crab *P. pelagicus* is one of the most significant commercial fisheries in the Gulf of Suez. Along the Egyptian coast of the Red Sea, most of the blue swimmer crab commercial catch comes from Suez Gulf (~ 248 ton) followed by the proper Red Sea and Aqaba Gulf (~ 52 ton). This is because the Suez Gulf has relatively shallow depths (do not exceed 90 m), muddy and sandy bottom with batches of rocks and reefs compared to the Red Sea and Aqaba Gulf (**El Komi and Emara, 2007; GAFRD, 2019**).

The life-history parameters of the blue swimming crab *P. pelagicus* have been much studied worldwide, while there have been few studies focusing on understanding the basic life-history traits of this species in Egypt. The available literature concerning the population features of *P. pelagicus* from the different Egyptian water bodies includes the studies of **Zaghloul (2003)** in Suez Bay; **Mehanna (2005)** in Bitter Lakes, Suez Canal; **Abdel-Razek *et al. (*2006)** in Bardawil Lagoon; **Mehanna and Haggag (2007)** in Mediterranean Sea, Port Said; **Mehanna and El-Aiatt (2011** in Bardawil Lagoon; **El-Far (2018)** in the Mediterranean Sea; **Ahmed (2019)** in Bardawil Lagoon; **Abdel Razek *et al.* (2019)** in Eastern Mediterranean Sea; **Sabrah *et al*. (2020)** in Bitter Lakes, Suez Canal;

El-Kasheif *et al.* (2021) in the Egyptian Red Sea. Some of the life-history parameters are unknown for the *P. pelagicus* inhabiting the Gulf of Suez, so the present study aimed to estimate these parameters for the blue swimmer crab *P. pelagicus* from the Gulf of Suez, Red Sea, Egypt for understanding the life history strategies of this commercially important species, so that establishing a fishery management plan.

MATERIALS AND METHODS

1. Sampling Regime, Species Identification, and Biological Data Collection:

Crabs are most commonly found in the muddy or sandy bottom along the Gulf of Suez (Fig. 1). They are mainly targeted by crab traps, gill net, and trammel net, also as bycatch of trawl. All the fishing boats and vessels operated in the fishing grounds along the Gulf of Suez were landed at Salakhana, Ataka, Ras Gharib, and El-Tor fishing ports. The blue swimmer crabs were sampled monthly from the landed catch at Salakhana and Ataka fishing harbor during the fishing season 2017/2018 and brought to the laboratory for further analysis.

These specimens were checked for species identification and then measured. The total weight (W g), Carapace Width (CW cm) “Distance between the tips of the largest spines” of each specimen were measured using a vernier caliper to the nearest 0.1 mm. Sex was distinguished by inspecting the shape of the abdominal flap on its underside; narrow or inverted "T" shaped for males, while females have an inverted "V" or triangular shape in juvenile females to an inverted "U" or bell-shaped in adult females. Also, the number of pleopods is "2 pairs for males and 4 pairs for females". Another differentiating feature is in their coloring; the colors vary from dark brown, dull blue-green, and purple, with pale mottling. Female blue swimmer crabs are less colorful than males; males always have blue-tipped claws, whilst females have orange-red tipped claws. The biometric measurements and tools for recognizing sex in the blue swimmer crab specimens according to that described by **Hill *et al.* (1989); Lai *et al*. (2010) and Efrizal *et al.* (2015)** were shown in Fig. (2). Both male and female crabs were directly dissected to ascertain their gonad development stages. The ovaries and testes were classified into four and three development stages based on the reproductive staging criteria developed by **De Lestang *et al.* (2003)**.

2. Life History Parameters:

The CW frequency data were collected on a monthly basis. The specimens were grouped in classes of 1 cm each. The life history parameters were divided into two categories; biological parameters and dynamical parameters. All parameters were investigated for each sex in separate as well as for combined sexes. Data analysis was executed using the spreadsheet Microsoft Excel 2019 and FiSAT II software.

2.1. Longevity (t_{max}):

The maximum age attained of *P. pelagicus* was approximated using the modal progression analysis [MPA] of **Bhattacharya's method (1967)** inserted in the FiSAT II computer program (**Gayanilo *et al.*, 2005**). This analysis allows the conversion of length-frequency data into age groups. This method is based on the following equation: ln (Ni+1) - ln (Ni) = aj + bj*Li Where: Ni and Ni+1 = successive frequencies of the same component of a group of specimens in a sample, Li = upper-class limit of Ni.

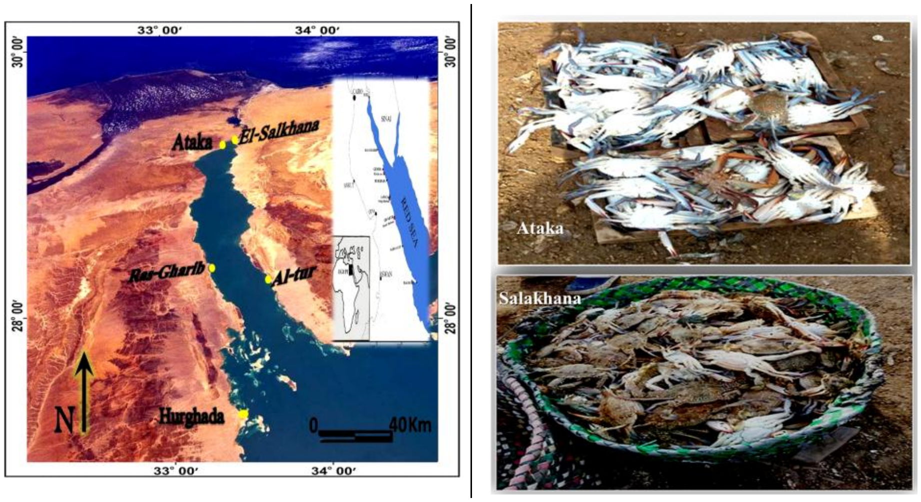

Fig. (1). Gulf of Suez map and the sampling from landing sites along the Suez Gulf.

Fig. (2). Biometric measurements and sexual dimorphism between male and female specimens of the blue swimmer crab *P. pelagicus*.

2.2 Sex Ratio (♂:♀):

The monthly sex ratio (M:F) for *P. pelagicus* was computed by dividing the number of females by the number of males and tested for statistical significance by the chi-square (χ^2) method based on the null hypothesis of a 1:1 ratio of male to female.

2.3 Fecundity (F):

Batch fecundity was estimated by taking a subsample of 60 ovigerous female crabs (20 specimens of each carapace width class group) based on the method described by **Johnson *et al.* (2010)**. The total egg batch (including the pleonal flap) was removed from the crab and immersed in 400 ml of 1M KOH for 12 h to dissolve the funiculae that attach the eggs to the setae. Following the separation process, the pleonal flap was removed, the pleopods scraped clean and all setae removed from the separated egg batch. The wet weight of the total separated egg batch was recorded and five replicate 0.02 g sub-samples were taken. The average number of eggs per sub-sample was then scaled up to estimate the total number of eggs per egg batch.

2.4 Carapace Width-Weight Relationship (CW-W):

The relationship between carapace width (CW) and total weight (W) was calculated using the modified equation $W = aCW^b$ from the original $W = aL^b$ (**Le-Cren, 1951**) for males, females, and pooled specimens. The regression analysis was performed and the values of the intercept (*a*) and the slope of the regression line (*b*) were calculated.

2.5 Growth Parameters:

The three parameters (CW_∞, K, and t_o) of the von Bertalanffy growth in length formula [VBGF]: $CW_t = CW_\infty\ (1- e^{(-k\ (t-t_o))})$ were estimated. The asymptotic carapace width CW_∞ (cm) and the growth coefficient K (yr^{-1}) were estimated through the direct fit of length-frequency (L/F) data using the methods of **Powell-Wetherall plot (Powell, 1979 and Wetherall, 1986)**, **ELEFAN I (Pauly, 1986)** and **Shepherd's method (Shepherd, 1987)** involved in the FiSAT II computer program (**Gayanilo *et al.*, 2005**). The hypothetical age t_o (yr) can be obtained as: $- \ln [1 - (Lt/L\infty)] = - Kt_o + Kt$; relating the age (t) and ($-\ln (1- (Lt/L\infty))$), having a slope (b) equals to (k) and an intercept (a) equals to ($-Kt_o$) then: $t_o = - a/b$. The asymptotic weight W_∞ (g) was calculated through the equation $W_\infty = a[CW_\infty]^b$. The growth performance index (Ø') was calculated from the formula: $Ø' = Log_{10} K + 2 Log_{10} L\infty$ (**Pauly and Munro 1984**).

2.6 Carapace width and age at first maturity, at first capture, and at recruitment:

Percentages of matured males and females (beyond the late maturing stage) were calculated for each 1 cm carapace width class and the ogive curve was fitted to estimate carapace width at first maturity (CWm). The carapace width at first capture (CWc) was computed by plotting the probability of capture curve. The carapace width at recruitment (CWr) was determined as the lower limit of the smallest carapace width class. The corresponding ages at first maturity (tm), at first capture (tc), and at recruitment (tr) were determined based on the re-arrangement of the typical VBGM as follow $t_m = t_o - (1/k \times \ln [1- (CW_m/CW_\infty)])$, $t_c = t_o - (1/k \times \ln [1- (CW_c/CW_\infty)])$, $t_r = t_o - (1/k \times \ln [1- (WC_r/CW_\infty)])$.

2.7 Mortality Parameters:

The total (Z), natural (M), and fishing (F) mortality coefficients were determined by numerous models and the average was taken. An estimate of Z was obtained by using the length-converted catch curve of **Pauly (1990)**, the cumulative plot of **Jones and van Zalinge (1981)**, **Hoenig's formula (1982)**, and **Ault and Ehrhardt's formula (1991)**. M was estimated using **Rikhter and Efanov's (1976)**, **Taylor's (1960)**, and **Ursin's (1967)** formula. F was calculated using the formula: $F = Z – M$.

2.8 Exploitation Ratio:

The exploitation ratio (E) was calculated as $E = F / Z$ **(Gulland, 1971).** The value of E gives a preliminary indication of the status of the *P. pelagicus* stock, as it allows one roughly assess whether a stock is overexploited or not.

RESULTS

1. Longevity (t_{max}):

MPA was depend on translating the length scale into an age scale. The results showed that the values of separation indexes (S.I) were > 2 indicating a minimal limit of overlap between classes in males, females, and combined sexes. The analysis revealed that the maximum age attained of *P. pelagicus* during the period of study was 2 yrs for females and 3 yrs for males (Table 1; Fig. 3). It was noticed that there is considerable differentiation in growth between males and females *P. pelagicus*. The maximum CW was 19 and 22 cm for females and males respectively.

2. Sex Ratio:

The sex ratio (♂:♀) of a total 537 specimens *P. pelagicus* (305 males and 232 females) in the Gulf of Suez was analyzed. The monthly distribution of males and females, sex ratio, and Chi-Square (χ^2) test were presented in Table (2) and Fig. (4). The results showed that the males dominated the natural population all over the fishing season 2017/2018 except April (males represented 56.2 %, while females represented 43.8 %). The overall sex ratio was 1:0.78 [$\chi^2 = 1.20$; $p = 0.52$]. The results are not statistically significant ($p > 0.05$), and hence do not reject the null hypothesis H_o of a 1:1 ratio of male to female.

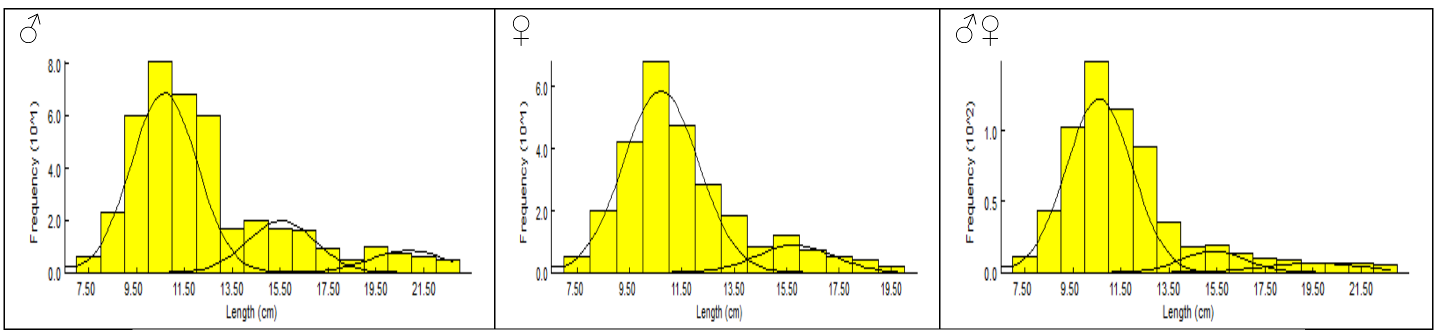

Fig. (3). The modal progression analysis for *P. pelagicus* using Bhattacharya's method.

Table (1): The estimated age groups (yr) and mean carapace width (cm) for *P. pelagicus* using Bhattacharya's method.

Age Group (yr)	Males				Females				Combined Sexes			
	Mean CW (cm)	**S.D.**	**NO.**	**S.I.**	**Mean CW (cm)**	**S.D.**	**NO.**	**S.I.**	**Mean CW (cm)**	**S.D.**	**NO.**	**S.I.**
1	10.86	1.45	315	n.a.	10.70	1.43	210	n.a.	10.60	1.37	420	n.a.
2	15.91	1.19	79	3.83	15.82	1.46	32	3.54	15.54	1.34	50	3.5
3	20.78	1.67	33	3.41	-	-	-	-	19.43	2.06	33	2.47

** S.D.: Standard Deviation. * NO.: Number of specimens fall in selection in each age group. * S.I.: Separation Index (> 2).*

Table (2): The monthly distribution of males and females, sex ratio, and Chi-Square (χ^2) test for *P. pelagicus* in the Gulf of Suez (September 2017 – April 2018).

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Grand Total
No. of males	37	37	45	57	31	47	26	25	305
No. of Females	31	29	25	38	22	36	25	26	232
Total	68	66	70	95	53	83	51	51	537
% of males	54.4	56.1	64.3	60.0	58.5	56.6	51.0	49.0	56.2
% of females	45.6	43.9	35.7	40.0	41.5	43.4	49.0	51.0	43.8
Sex Ratio (♂:♀)	1: 0.84	1: 0.78	1: 0.56	1: 0.67	1: 0.71	1: 0.77	1: 0.96	1: 1.04	1: 0.78
χ^2	1.22	1.32	1.02	1.03	1.11	1.00	1.25	1.64	1.20
p-value	0.51	0.48	0.52	0.51	0.33	0.54	0.61	0.69	0.52

** CV (chi-squared Critical Value) = 6.19* **Level of significance "p-value 0.05"*

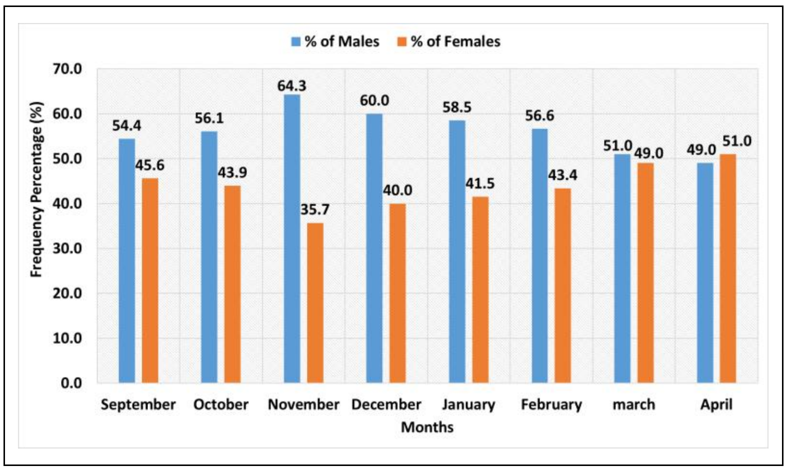

Fig. (4). The monthly percentages of males and females *P. pelagicus*, collected from the Suez Gulf (September 2017 – April 2018).

3. Fecundity:

The estimates of fecundity (± SD) of *P. pelagicus* ovigerous females in the Gulf of Suez for pooled data during all seasons of the year from September 2017 – April 2018 were given in Table (3). From results, it was observed that the blue swimmer crab *P. pelagicus* characterized by high fecundity. The average fecundity was calculated as 407338 (±35529), 617937 (±42086) and 793928 (±37610) eggs per batch for a mean carapace width of 10.7, 14.6, and 18.1 cm. From results, it was observed that the fecundity increased with increasing the carapace width over the size range examined.

Table (3): Carapace width range (cm) and estimates of fecundity (± SD) for *P. pelagicus* in the Gulf of Suez.

Carapace Width (cm)	Mean Carapace Width (cm)	Min. Fecundity	Max. Fecundity	Mean Fecundity	SD
9 – 12	10.7	337943	476962	**407338**	35529
13 – 16	14.6	512311	696389	**617937**	42086
17 – 20	18.1	688923	869417	**793928**	37610

** No. of specimens of each carapace width class group = 20*
** SD: Standard Deviation*

4. Carapace Width-Weight Relationship (CW-W):

The carapace width and total weight measurements of 537 specimens of *P. pelagicus* ; 305 males (7.7 – 22.9 cm CW & 28.6 – 495.8 g W) & 232 females (7.2 – 19.7 cm CW & 25 – 394.3 g W) were used to study CW-W relationship. The output of the simple non-linear regression analysis between CW (*x*) and W (*y*) was given in Table (4) and the obtained plots were shown in Fig. (5). The estimated CW-W relationship equations were [$W= 0.0175\ CW^{3.277}$, $R^2= 0.9451$], [$W= 0.0242\ CW^{3.273}$, $R^2= 0.9278$], and [$W= 0.0171CW^{3.276}$, $R^2= 0.9358$] for males, females and combined sexes respectively.

Table (4): Simple non-linear regression analysis between CW (*x*) and W (*y*) for *P. pelagicus* in the Gulf of Suez.

Sex	Species Characteristics			Regression Analysis			Growth Pattern
	Sample Size (n)	CW (cm)	W (g)	*a*	*b*	R^2	
Males	305	7.7 – 22.9	28.6 – 495.8	0.0175	3.277	0.9451	+ *ve* AG
Females	232	7.2 – 19.7	25.0 – 394.3	0.0242	3.273	0.9278	+ *ve* AG
Combined Sexes	537	7.2 – 22.9	25.0 – 495.8	0.0171	3.276	0.9358	+ *ve* AG

** a: y-intercept.* ** b: Regression Coefficient.* *$*R^2$: Coefficient of determination.*
** + ve* AG*: Positive Allometric Growth.*

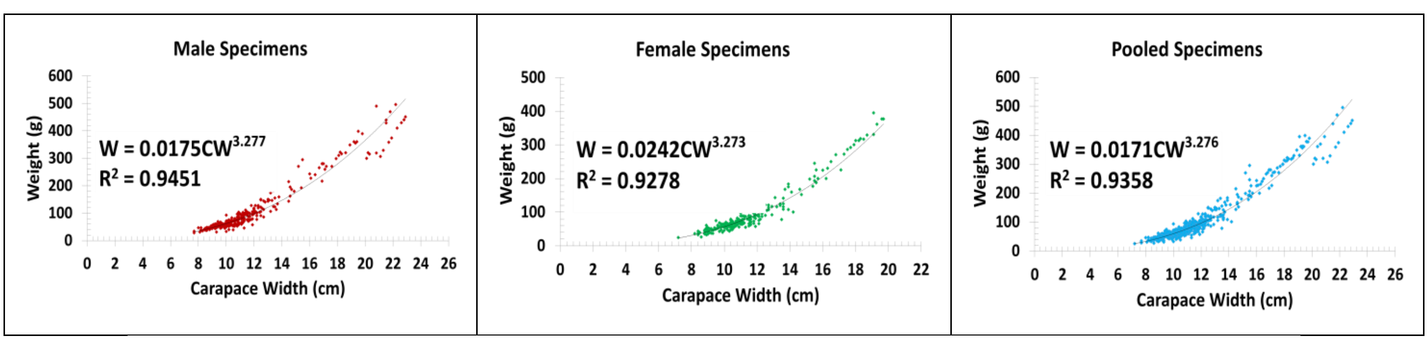

Fig. (5). The CW-W relationship for *P. pelagicus* in the Gulf of Suez.

5. Growth Parameters:

The estimated values of the von Bertalanffy growth parameters (CW_{∞}, K, t_o, and W_{∞}) as well as the growth performance index (Ø') for the blue swimming crab *P. pelagicus* males, females, and combined sexes were given in table (5) and demonstrated in Figs. (6, 7, and 8). The average values of CW_{∞} and K of the three applied methods were (23.83 cm, 0.78 / yr), (20.44 cm, 0.93 / yr), and (23.86 cm, 0.89 / yr) for males, females, and combined sexes respectively. The K-value was higher in females (0.93 / yr) than in males (0.78 / yr). The asymptotic weights ($W\infty$) obtained from the asymptotic carapace widths ($CW\infty$) were 570.0, 471.0, and 557.0 g. for males, females, and combined sexes respectively. The hypothetical age (t_o) were 0.27, 0.01, and 0.02 yr for *P. pelagicus* males, females, and combined sexes respectively. The computed growth performance index (Ø') were 2.65, 2.59, and 2.70 for *P. pelagicus* males, females, and combined sexes respectively.

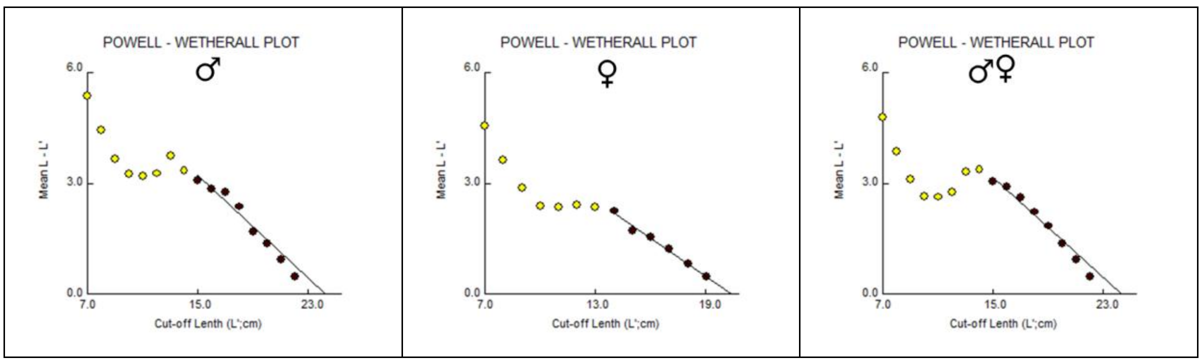

Fig. (6). Powell-Wetherall's plot for the estimation of CW∞ for *P. pelagicus* in the Gulf of Suez.

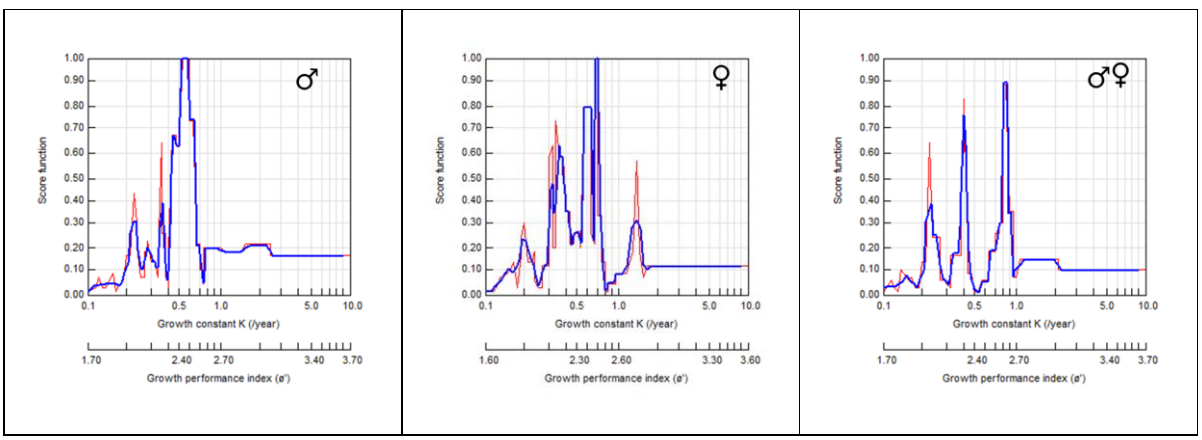

Fig. (7). Non-parametric scoring of VBGF fit using ELEFAN I for *P. pelagicus* in the Gulf of Suez.

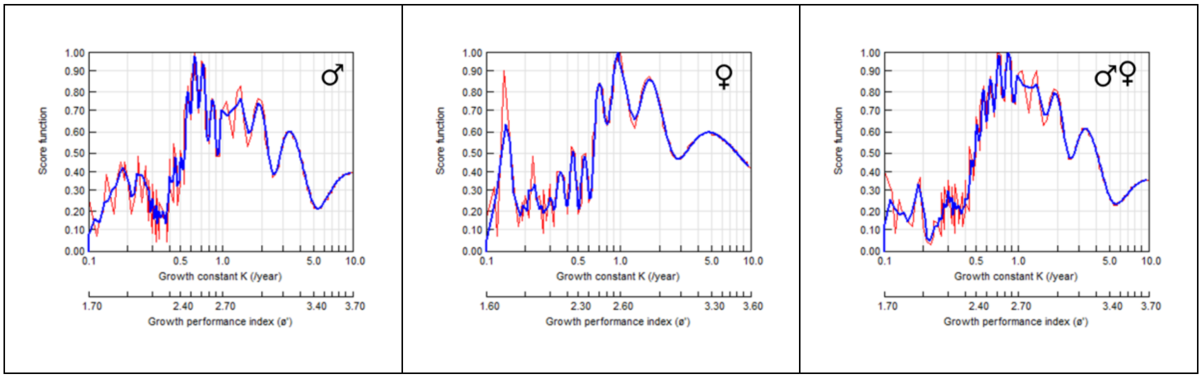

Fig. (8). Maximizing Non-parametric scoring of VBGF fit using Shepherd's method for *P. pelagicus* in the Gulf of Suez.

6. Carapace width and age at first maturity, at first capture, and at recruitment:

The mean carapace width and the corresponding mean age at first maturity (CWm & tm), at first capture (CWc & tc), as well as at recruitment (CWr & tr) were determined for *P. pelagicus* males, females, and combined sexes (Figs. 9 & 10). The estimated values of CWm were (9.6, 9.8, and 9.4 cm) and the corresponding tm was (0.93, 0.71, and 0.58 yr) for males, females, and combined sexes respectively. The determined values of CWc were (7.4, 7.5, and 7.2 cm) while tc was (0.74, 0.50, and 0.42 yr) for males, females, and combined sexes respectively. Further, the obtained values of CWr were (7.7, 7.2, and 7.2 cm) and tr was (0.77, 0.48, and 0.42 yr) for males, females, and combined sexes respectively.

Table (5): The estimated von Bertalanffy growth parameters and the growth performance index for *P. pelagicus* in the Gulf of Suez.

Sex	Powell-Wetherall		ELEFAN I		Shepherd		$\bar{X}$		W_∞ (g)	t_o (yr)	Ø'
	CW_∞ (cm)	Z/K	CW_∞ (cm)	K (/yr)	CW_∞ (cm)	K (/yr)	CW_∞ (cm)	K (/yr)			
Males	24.22	1.866	23.63	0.61	23.63	0.73	**23.83**	**0.78**	**570.0**	**0.27**	**2.65**
Females	20.40	1.904	20.48	0.78	20.48	1.0	**20.44**	**0.93**	**471.0**	**0.01**	**2.59**
Combined Sexes	24.32	1.938	23.63	0.81	23.63	0.86	**23.86**	**0.89**	**557.0**	**0.02**	**2.70**

** $\bar{X}$: The Arithmetic Mean.*

** All methods were involved in the FiSAT II software [Revised version 1.2.0].*

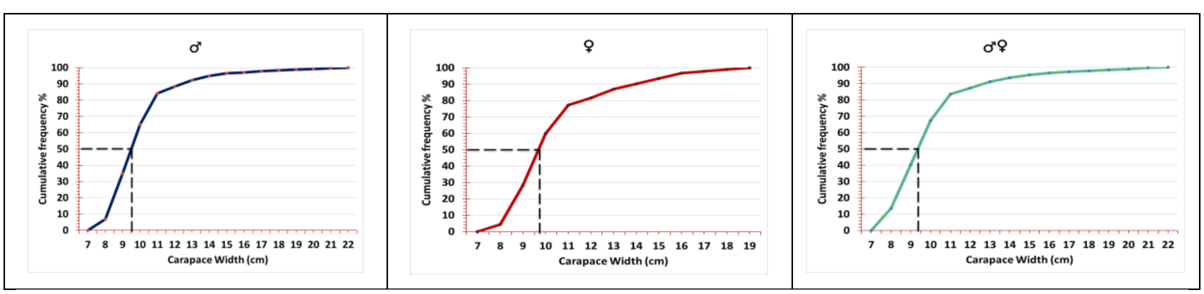

Fig. (9). Maturation curves to estimate the CW at first maturity for *P. pelagicus* in the Gulf of Suez.

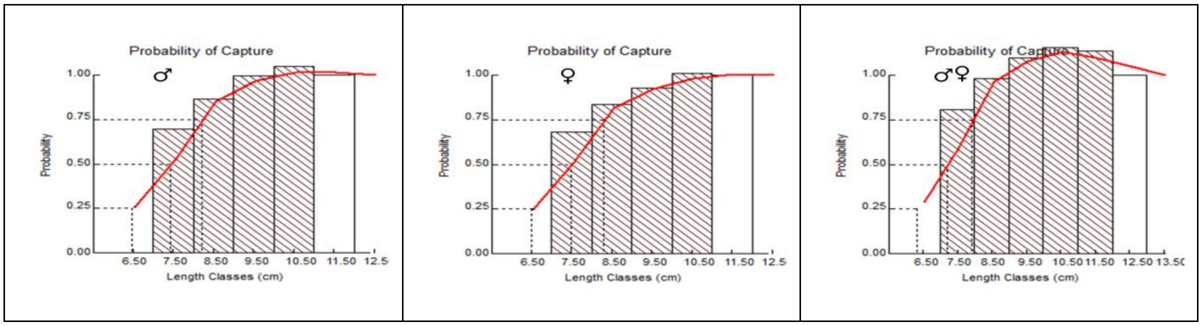

Fig. (10). The probability of capture to estimate the CW at first capture for *P. pelagicus* in the Gulf of Suez.

7. Mortality Parameters:

The estimated values of total mortality coefficient "Z" as well as that of natural mortality coefficient "M" for *P. pelagicus* males, females, and combined sexes, and their average values were given in table (6) and graphically represented in Figs. (11 and 12). The average values of all utilized methods for the estimation of Z were 2.44, 3.41, and 2.89 /yr for males, females, and combined sexes respectively. While, the averages of the estimated values of M were 0.90, 1.17, and 1.09 / yr for males, females, and combined sexes respectively. Further, the determined values of fishing mortality coefficients "F" were 1.54, 2.24, and 1.80 / yr for males, females, and combined sexes respectively.

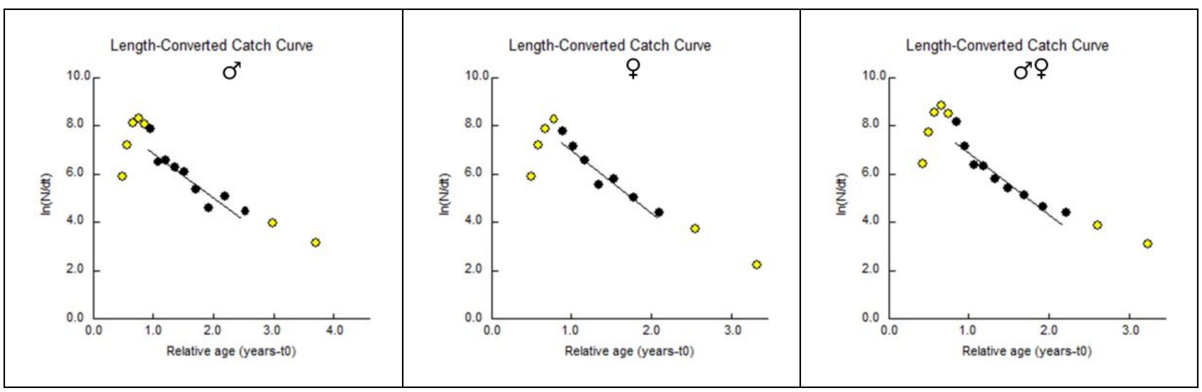

Fig. (11). The length-converted catch curve of Pauly for *P. pelagicus* in the Gulf of Suez.

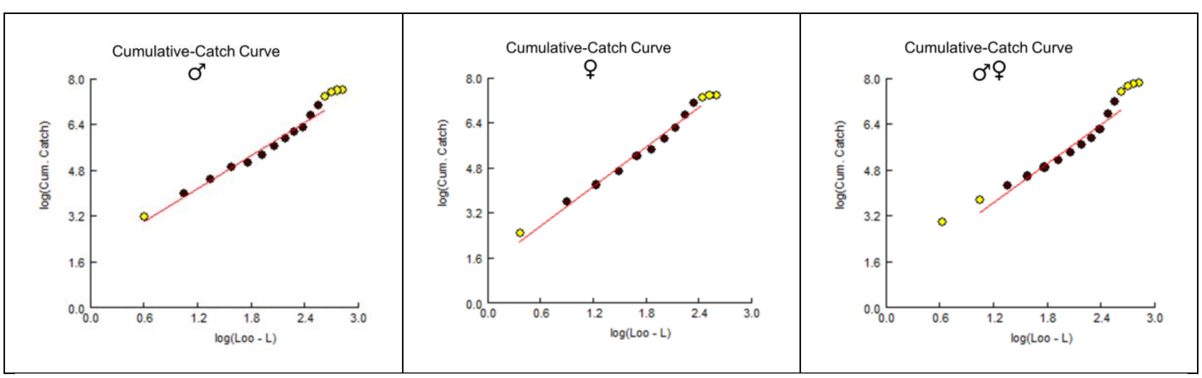

Fig. (12). The cumulative plot of Jones and van Zalinge for *P. pelagicus* in the Gulf of Suez.

8. Exploitation Ratio:

The determined values of exploitation ratio "E" were 0.63, 0.66, and 0.62 for *P. pelagicus* males, females, and combined sexes respectively.

Table (6): The estimated mortality coefficients (Z and M) for *P. pelagicus* in the Gulf of Suez.

Sex	Z (/yr)					M (/yr)			
	Pauly	Jones and van Zalinge	Hoenig	Ault and Ehrhardt	$\bar{X}$	Rikhter and Efanov	Taylor	Ursin	$\bar{X}$
♂	3.16	3.29	1.43	1.89	**2.44**	1.49	1.0	0.21	**0.90**
♀	4.89	4.75	2.13	1.86	**3.41**	1.79	1.5	0.22	**1.17**
♂♀	3.47	4.28	1.43	2.40	**2.89**	2.06	1.0	0.21	**1.09**

* $\bar{X}$ *: The Arithmetic Mean.*

** All methods were involved in the FiSAT II software [Revised version 1.2.0], except the Taylor's, as well as Ursin's methods, were calculated using the spreadsheet Microsoft Excel.*

DISCUSSION

Overexploitation of different finfish and shellfish stocks worldwide is due to they are not adequately managed, as a result, catches are declining. However, for sustainable management of crab fishery *P. pelagicus* in the Gulf of Suez, it was important to have a genuine knowledge of all life history traits which gives the necessary information for successful fisheries management. The blue swimmer crab *P. pelagicus* in the Gulf of Suez is a very common, economically important shellfish species, that forms part of the gill net, traps, and trawl fishery in the Gulf of Suez.

The analysis of the grouped carapace width-frequency data using MPA exhibited that the maximum age attained of *P. pelagicus* in the Gulf of Suez during the present study was 2 yrs for females (Max. CW = 19 cm) and 3 yrs for males (Max. CW = 22 cm). These results were relatively similar to that obtained by **Mehanna and Haggag (2007)** who estimated the longevity of 2 yrs for *P. pelagicus* collected from the Mediterranean coast of Egypt. Also, **Dineshbabu *et al.* (2008)** who recorded 3 yrs of longevity for both males and females *P. pelagicus* from the south Karnataka coast, India. In contrast, **El-Kasheif *et al.* (2021)** estimated longevity of 4 yrs for *P. pelagicus* male and female individuals (Max. CW = 14.0 and 14.1 cm respectively) from the Red Sea, Egypt. Generally, our results fall in the range given by previous workers who mentioned that *P. pelagicus* is a short-lived and fast-growth species, its maximum life span ranged from one to four years.

The obtained sex ratio (♂:♀) of *P. pelagicus* in the Gulf of Suez was 1:0.78 which does not statistically significant from the ideal 1:1 ratio ($p > 0.05$). Similarly, the recorded sex ratio by **Dineshbabu *et al.* (2008)** from south Karnataka coast, India. Also, the results of the present investigation agreed with that documented by **Mehanna *et al.*, (2013)** in Oman [1♂:0.71♀] and **La Sara *et al.* (2016)** in Southeast Sulawesi waters, Indonesia [1 ♂:1.032 ♀]. In contrast, **Jayawiguna *et al.* (2017**) reported a sex ratio of 1.3:1 between males and females *P. pelagicus* in Jakarta Bay, Indonesia. Also, **Suman *et al.* (2020)** recorded a sex ratio of males to females (1.0:1.7) in the South Kalimantan. The sex ratio may vary from species to species, or even in the same population at different times, as it influenced by several factors such as adaptation of the population, reproductive behavior, food availability, and environmental conditions.

The average fecundity (F) of *P. pelagicus* in the Gulf of Suez of the present investigation has been observed to vary from 407338 (±35529) to 793928 (±37610) eggs per individual for a mean carapace width varied from 10.7 to 18.1 cm. These findings indicated high fecundity for this species in the Gulf of Suez, which also was referring to the increasing F with increasing CW. Our estimates of fecundity concur with that of **Razek (1988)** (750000 to 810000 eggs), **Johnson *et al.* (2010)** estimated the fecundity of *P. pelagicus* inhabiting Wallis Lake in Australia, from approximately 463,000 to 1,781,000 eggs per batch, while **La Sara *et al.* (2016)** found that F was ranged between 763,413 to 2,868,284 eggs in Southeast Sulawesi waters, Indonesia. Also, they verified that the fecundity increased linearly with the carapace length (CL). The disparity in fecundity between different studies can be attributed to several factors; differences from one season to another and to environmental conditions.

The estimated CW-W relationship equations for the *P. pelagicus* in the present investigation revealed that the b-value was > 3, indicating a positive allometric growth (+*ve* AG) for both males and females, which implies that the blue swimmer crab becomes relatively fatter with increasing CW. The value of the coefficient of determination (R^2) is typically taken as the percent of variation shared between the two variables CW & W. The high values of the coefficients of determination (R^2 = 0.94, 0.93, and 0.94 for males, females, and combined sexes respectively) indicate the high accuracy of these models where the value is close to one.

The previous studies revealed different growth types fluctuated among +*ve* AG as in the present study, -*ve* AG and isometric growth (Table 7). The parameters of the CW-W relationship between different studies for the same species, and even between sexes within the same study may vary significantly due to the biological and environmental conditions or geographical, temporal, and sampling factors (**Froese, 2006**).

The very small-sized individuals (CWr = 7.7 cm and 7.2 cm for males and females respectively) is indicating very small mesh sizes that prevent them from escaping. This is an indicator of a growth-overfishing, where they were harvested too small before they have grown to harvestable sizes and before being helped to replenish the population. Moreover, it was clear that the values of CWm (9.6 cm ♂ and 9.8 cm ♀) were greater than the values of CWc (7.4 cm ♂ and 7.5 cm ♀); referring that they were caught before attaining maturity, at least they should reproduce once or two times in its life cycle. The CWc obtained from the present study was more or less similar with the previous studies. Variations in the determined values of CWc and the corresponding tc between different studies might be attributed to the differences in the selectivity of the fishing gears used to obtain samples.

Regarding the values of CWm [9.6 ♂ and 9.8 ♀] for *P. pelagicus* in the present study. **De Lestang *et al.* (2003)** gave a similar estimate of CWm for *P. pelagicus* from shark bay, Australia [9.6 cm ♂ and 9.2 cm ♀]. Also, similar results of size at maturity (50%) of females *P. pelagicus* from south Karnataka coast, India was at 9.6 cm CW as referenced by **Dineshbabu *et al.* (2008)**.

Table (7): Carapace Width-Weight Relationship of *P. pelagicus* of the present study and of previous studies.

Source	Region	Sex	CW–W Equation	CW range (cm)	W range (g)
Dineshbabu *et al.* (2008)	South Karnataka coast, India	♂	$W = 0.020056CW^{3.4864}$	5.6 – 16.5	-
		♀	$W = 0.02852\ CW^{3.22063}$	6.1 – 17.0	-
		♂♀	-	-	-
Kamrani *et al.* (2010)	Northern Persian Gulf	♂	b = 2.757	-	-
		♀	b = 2.748	-	-
		♂♀	-	-	-
Mehanna *et al.* (2013)	Oman	♂	$W = 0.00002CW^{3.2401}$	5.7 – 19.3	-
		♀	$W = 0.00007\ CW^{3.0061}$	8.4 – 20.6	-
		♂♀	$W= 0.00003\ CW^{3.2109}$	5.7 – 20.6	-
Basri (2016)	Toronipa waters, Indonesia	♂	b = 2.703	-	-
		♀	b = 2.964	-	-
		♂♀	-	-	-
Jayawiguna *et al.* (2017)	Jakarta Bay, Indonesia	♂	$W = 0.00003CW^{3.203}$	-	-
		♀	$W = 0.00009CW^{2.947}$	-	-
		♂♀	$W = 0.00004CW^{3.122}$	6.25 – 15.25	-
Rohmayani *et al.* (2018)	Java Sea, Indonesia	♂	$W = 0.033CW^{3.325}$	7.80 – 14.40	57.01 – 246.02
		♀	$W = 0.041CW^{3.183}$	7.14 – 19.54	23.02 – 248.01
		♂♀	$W = 0.039CW^{3.222}$	7.80 – 19.54	23.02 – 248.01
Haputhantri *et al.* (2021)	Palk Bay, Sri Lanka.	♂	$W = 0.0001CW^{3.01}$	7.0 – 18.5	31.0 – 573.0
		♀	$W = 0.0001CW^{2.90}$	6.7 – 18.5	31.0 – 572.0
		♂♀	$W = 0.0001CW^{2.97}$	6.7 – 18.5	31.0 – 573.0
El-Kasheif *et al.* (2021)	Red Sea, Egypt	♂	$W = 0.0513\ CW^{3.1281}$	5.25 – 14.0	11.5 – 225.0
		♀	$W = 0.0574\ CW^{3.0709}$	5.32 – 14.1	14.5 – 228.0
		♂♀	$W = 0.0513\ CW^{3.1012}$	5.25 – 14.1	11.5 – 228.0
Present Study	Gulf of Suez, Egypt	♂	$W = 0.0175CW^{3.277}$	7.7 – 22.9	28.6 – 495.8
		♀	$W = 0.0242CW^{3.273}$	7.2 – 19.7	25.0 – 394.3
		♂♀	$W = 0.0171CW^{3.276}$	7.2 – 22.9	25.0 – 495.8

The present study indicated that *P. pelagicus* reaches sexual maturity within one year (0.93 yr for males and 0.71 yr for females) which agreed with the findings of **Dineshbabu *et al.*, 2008** (8 months). Otherwise, **La Sara *et al.* (2016)** shared higher estimates of CWm [11.9 cm ♂ and 10.8 cm ♀] for CW ranging from 7.6 - 15.8 cm ♂ and 7.2 - 15.9 cm ♀ of *P. pelagicus* in Southeast Sulawesi waters, Indonesia. Furthermore, **Jayawiguna *et al.* (2017)** determined a relatively higher value of CWm for *P. pelagicus* pooled samples collected from Jakarta Bay Waters, Indonesia (CWm = 10.54 cm). Also, **Suman *et al.* (2020)** determined a higher value of CWm for *P. pelagicus* inhabiting the Tanah Laut, South Kalimantan (CWm = 13.32 cm). Differences in the values of CWm and the corresponding tm for *P. pelagicus* in different regions worldwide could be due to the regional environmental conditions that affect the annual maturation of gonads.

The estimates of growth parameters for *P. pelagicus* in the present study differed from other studies in several ways despite similar methods. **Dineshbabu *et al.* (2008)** gave all the growth parameters for the blue swimmer crab, *P. pelagicus* from South Karnataka coast, India. They found the values of CW_∞, K, t_o, and $W\infty$ were (16.9 cm, 1.3 yr^{-1}, -0.0428 yr) and (17.0 cm, 1.4 yr^{-1}, and -0.0384 yr) for males and females respectively. During the present study, the K-value was higher in females than in males (0.78 yr^{-1} for males and 0.93 yr^{-1} for females), which agree with the findings of **Dineshbabu *et al.*, 2008** (K = 1.3 yr^{-1} and 1.4 yr^{-1} for males and females respectively. The estimated growth parameters (CW_∞, K) for *P. pelagicus* combined sexes from the Tanah Laut, South Kalimantan as reported by **Suman *et al.* (2020)** were 20.43 cm and 1.1 yr respectively. **El-Kasheif *et al.* (2021)** also reported the parameters of the von Bertalanffy growth equation for *P. pelagicus* combined sexes from the Red Sea, Egypt and the results were 21.19 cm, 0.414 yr^{-1}, and - 0.998 yr for CW_∞, K, and t_o respectively. Differences in the values of the growth parameters [CW_∞, K, t_o, and $W\infty$] for *P. pelagicus* in the present study and those of other previous studies could be imputed to several factors such as food availability, water quality parameters specifically seawater temperature, and salinity, as well as the depth from which collected. Also, due to variation in the size range (max. CW and W) sampled during the study.

During the path of the present investigation, the average values of mortality coefficients [Z, M, F] of *P. pelagicus* were (2.44, 3.41, and 2.89 / yr), (0.90, 1.17, and 1.09 / yr), and (1.54, 2.24, and 1.80 / yr) for males, females, and combined sexes respectively. The determined values of exploitation ratio [E] were 0.63, 0.66, and 0.62 for *P. pelagicus* males, females, and combined sexes respectively, which seemed to be higher in females (E = 0.66) than males (E = 0.63). Further, these values are higher than the optimum level of exploitation (E = 0.5), this is based on the assumption that a stock is optimally exploited at E = 0.5 when F equals M (**Gulland, 1971**). Therefore, these high values indicate that the stock of *P. pelagicus* males and females were overexploited (E > 0.5), and the females were more intensively exploited than the males. This might be due to excessive fishing on berried females than male individuals for their higher price. The results had indicated that females have higher instantaneous rate of the total, natural, and fishing mortality than males. Also, the higher values of F than M in both sexes, reflecting an over-fishing condition for the males and females *P. pelagicus* in the Gulf of Suez.

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