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Original Article

Population structure, stock assessment, and fisheries management of blue swimming crab *Portunus pelagicus*, Linnaeus 1758, in the eastern Mediterranean Sea

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ABSTRACT: Although there are many fisheries studies on Egyptian western Mediterranean Sea coasts, a few of them concern with Egyptian eastern Mediterranean Sea fisheries. During this study, 924 specimens of blue swimming crab caught along the eastern Mediterranean Sea during fishing season 2022/2023 for management of *Portunus pelagicus* fisheries. Minimum and maximum carapace widths was 5.5 – 13.5 cm for males and 6.4 – 13.2 cm for females. Estimated Von Bertalanffy growth parameters were L∞= 17.82 cm; K= 0.15 y-1; t0= - 1.28 yr-1 for males, L∞= 17.41 cm; K= 0.15 yr-1; t0= - 1.41 yr-1 for females, and L∞= 17.68 cm; K= 0.17 yr-1; t0= - 1.19 yr-1 for combined sexes. Estimation of the yield per recruit on the region, shows the crab stock is being exploited beyond its maximum biological limit, but the increasing of fishing mortality to the level which gives the maximum Y/R need to increase the fishing with 824% of its current value, will cause an insignificant increase in Y/R by 15% and a considerable decrease in biomass per recruit and reach only 4% from the virgin stock. That indicates the *P. pelagicus* population is overfished in the eastern Mediterranean Sea fisheries. Accordingly, the recommended procedure for reduction of fishing efforts or changing the mesh sizes of bottom trawl gear must apply.

Key word: The blue swimming crab, *Portunus pelagicus*, Exploitation rate, and Fisheries Management

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1. INTRODUCTION

According to global fisheries statistics, production from inland and marine fisheries has gradually declined from the nineteenth till now (FAO, 2023). Consequently, the decline occurs in the blue swimming crab *Portunus pelagicus* population all over the global fishery. In the Eastern Mediterranean Sea, North Sinai, the blue swimming fisheries statistics have had a noticeable fluctuation catch during recent years (GAFRD, 2020).

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In the fishing season 2016, the blue swimming crab represented about 29% of the overall North Sinai fishery, Egyptian east Mediterranean Sea part total catch (GAFRD, 2016). On the other hand, it has significant economic importance in this part, as it serves as one of the major fishery exports of the governorate .

The blue swimming crab *P. pelagicus* is a tropical and subtropical species that found on exposed sandy beaches of the north-east Atlantic and parts of the Mediterranean, in the Indo-Pacific and the intertidal estuaries around most of Australia and east to New Caledonia (FWA, 2011). No previous studies deal with the blue swimming crab biology, ecology, and population parameters in the eastern Mediterranean Sea fishery. *P. pelagicus* is caught as a target species by trawls and trammel net within this area. Also, it is a significant prey of several commercial species such as, sea bass *Dicentrarchus labrax*, gilthead seabream *Sparus aurata*, and white seabream *Diplodus sargus*.

Portunus pelagicus is found in variety habitats and distributes from the intertidal zone to a depth of around 50-65 m and estuaries to the open sea. Also, it preferring to live on muddy or sandy bottoms or algal and seagrass habitat (Williams, 1982; Sumpton et al., 1989 and Edgar, 1990).

The final objectives of this study are i) to describe the population characteristics of the blue swimming crab *Portunus pelagicus* from the eastern Mediterranean Sea fishery. ii) to examine the gender variations of theoretical growth facts on this Decapoda species. iii) to determine other main parameters of its population dynamics, such as total mortality, natural mortality, and fishing mortality. v) to assess its exploitation rate, stock condition, and to manage this significant crustacean resource in the eastern Mediterranean Sea fishery via this study. These parameters will enable us to estimate the crab stock in the Mediterranean Sea and helping to make necessary recommendations for the responsible catch and sustainable management of this valuable marine resource.

2. MATERIALS AND METHODS

2.1.Study area

The eastern portion of the Mediterranean Sea basin includes, the Adriatic Sea, the Ionian Sea, the Aegean Sea, and the Levantine Sea (MSP, 2023). Egyptian coasts from Rafah to El Sallum concluded in the Levantine Sea. Most of the river discharge is from the Nile. Since the Aswan High Dam sits across the river in the 1960s, it has facilitated the multiplication of Egyptian agriculture and population. It has reduced, to the sea, the flow of freshwater, mountainous minerals in the silt, and the distance traveled by the it (before this, borne by floodwater). These makes the sea slightly saltier and nutrient-poorer than before (Map 1).

Map 1. Eastern Mediterranean Sea fishery, North Sinai coast. From European MSP Platform.

2.2. Sampling and Data Analysis

Random samples of the blue swimming crab collected monthly from the commercial catch of eastern Mediterranean Sea fishery and from local market during the fishing season 2022/2023. The blue swimming crab sexes were separated by male and female then sampled randomly from the catch. The following measurements taken on all specimens; the carapace length (CL) is measured along the anterior-posterior axis, whereas the carapace width (CW) measured from side-to-side to the nearest centimeter, and the total body weight to the nearest tenth of a gramme. The length frequencies grouped into 0.2 cm classes. Data were processed and analyzed to estimate the population parameters.

The blue swimming crab growths were estimated seasonally for males and females. Constants of von Bertalanffy's, 1938 theoretical growth equation were calculated by applying (Gulland and Holt, 1959) plot. Estimation of the theoretical age at zero length (t0) done by the equation:

$\log_{10}(-t_0) = -0.3922 - 0.275 * \log_{10} L\infty - 1.038 * \log_{10} K$ (Pauly, 1979).

The growth performance index (Φ) equation presented by Munro and Pauly, (1983) from the maximum growth rate formula based on some biological and empirical consideration. The length at first capture (Lc) calculated from the probability of 50% of cumulative length catch curve .

Instantaneous mortality coefficients "Z, M, and F" estimated to determine the population structure of *P. pelagicus.* The total mortality coefficient "Z" was estimated from a linearized length converted catch curve (Van Sickle, 1977 developed by Pauly, 1983). Instantaneous natural mortality coefficient "M" was estimated by the empirical equation suggested by Pauly, 1980, as: $\log M = -0.0066 - 0.279 \log L\infty + 0.6543 \log K + 0.4634 \log T$, where T: is the annual mean temperature (in °C) of the water in which the stock lives.

The fishing mortality coefficient "F" was estimated by subtracting the natural mortality coefficient from the total mortality coefficient. The exploitation rate "E" was estimated by the formula suggested by Gulland (1971). Estimation of survival rates "S" as a number of fish alive after a specified time interval, divided by the initial number, usually on a yearly basis was done according to Ricker, 1975, equation.

The yield per recruit (Y/R) was estimated by Gulland's, 1969 model. Beverton and Holt, (1957) reported the biomass per recruit (B/R) model was obtained by the equation: B/R = (Y/R)/F, where "F" is the fishing mortality. Biological reference points "R/B", "F_{max}" and "$F_{0.1}$" were obtained according to (Cadima, 2003). The effects of age and length at the first capture on yield per recruit at the present value of fishing mortality and at different fishing mortality values were estimated, the ratio $F_{cur}/F_{0.1}$ was calculated to indicate the stock status.

3. RESULTS

Management of *P. pelagicus* fisheries in the eastern Mediterranean Sea is serious about providing some enough advice for optimum harvest levels that provide maximum yield on a long-term basis.

3.1. Growth

3.1.1. Growth in length

A total of 531, 393, and 924 males, females, and both sexes specimens of blue swimming crab sampled, carapace length and width measured, and back-calculated carapace widths calculated. The back-calculated carapace width (CW) for both sexes was 6, 8, 9.2, 10.4, 11.6, and 12.6 cm for seasonal (ages) 1, 2, 3, 4, 5, and 6 seasons respectively. The seasonal increments incarapace lengths were 6.4, 2, 1.2, 1.2, 1.2, and 1 cm for ages 1, 2, 3, 4, 5, and 6 seasons respectively (Table 1 and Fig. A, B, and C).

Table 1. Growth in length and seasonal increments of *P. pelagicus* in the eastern Mediterranean Sea.

Age (season)	Both sexes		*Males*		*Females*	
	Length (cm)	***Increments***	***Length (cm)***	***Increments***	***Length (cm)***	***Increments***
1	6.00	6.00	6.40	6.40	6.40	6.40
2	8.00	2.00	8.40	2.00	8.00	1.60
3	9.20	1.20	9.60	1.20	9.20	1.20
4	10.40	1.20	10.40	0.80	10.00	0.80
5	11.60	1.20	11.00	0.60	11.00	1.00
6	12.60	1.00	12.60	1.60	12.00	1.00

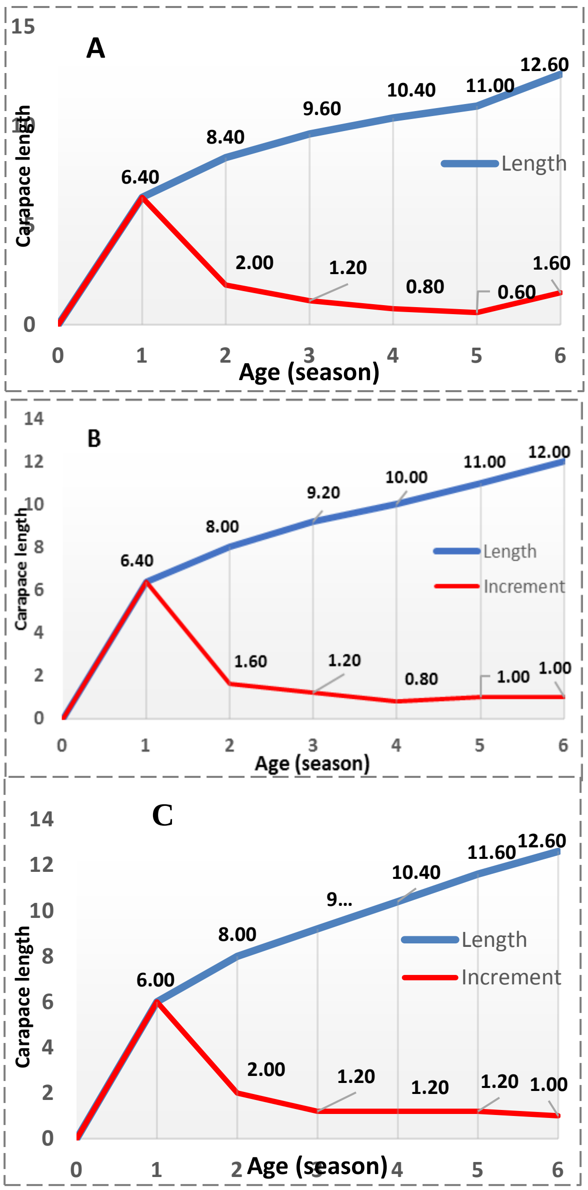


Fig. A, B, and C. Growth in length and seasonal increments of *P. pelagicus* in the eastern Mediterranean Sea. A) males, B) females, and C) all individuals .

3.1.2. Growth in weight

The observed total weights of the blue swimming crab ranged between 29 and 333 grams. The back-calculated total weight for both sexes was 31.52, 60.36, 89.83, 127.31, 173.69, and 219.75 gm for seasonal (ages) 1, 2, 3, 4, 5, and 6 seasons, respectively. The seasonal increments in carapace lengths were 31.52, 28.84, 29.47, 37.48, 46.38, and 46.06 gm for ages 1, 2, 3, 4, 5, and 6 seasons respectively (Table 2& Fig. d, e, and f).

3.2. Theoretical growth in length and weight

Equation of von Bertalanffy's, 1938 assessed to determine the theoretical P. pelagicus growth in length and weight by fitting Gulland and Holt (1959) plot. Parameters of von Bertalanffy's equation CW_∞, K, t_0, and W_∞ measured and its values represents in (Table 3).

The growth performance index (Φ) is a tool for growth comparison either between species or between same species at different stock.

3.3. Growth performance index

Table 2. Growth in weight and seasonal increments of *P. pelagicus* in the eastern Mediterranean Sea.

Age (season)	Both sexes		*Males*		*Females*	
	Weight (gm)	***Increments***	***Weight (gm)***	***Increments***	***Weight (gm)***	***Increments***
1	31.52	31.52	31.29	31.29	32.21	32.21
2	60.36	28.84	58.47	27.19	70.84	38.63
3	89.83	29.47	86.51	28.04	104.32	33.48
4	127.31	37.48	109.29	22.78	131.56	27.24
5	173.69	46.38	142.76	33.47	154.78	23.23
6	219.75	46.06	182.18	39.43	229.44	74.66

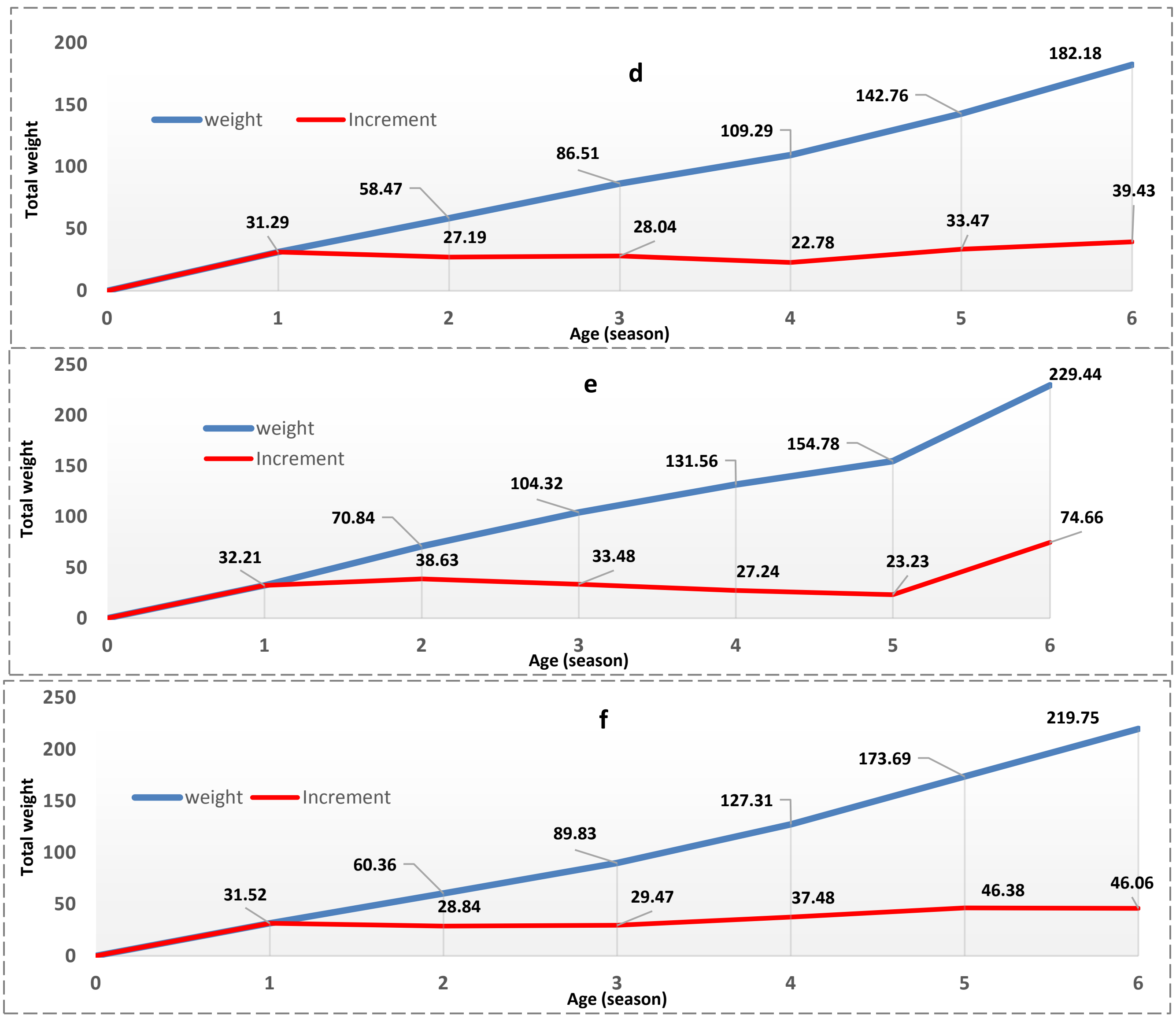


fig. (d, e, and f). Growth in weight and seasonal increments of *P. pelagicus* in the eastern Mediterranean Sea. *d) males, e) females, and f) all individuals.*

The growth performance (Φ) of the blue swimming crab found Φ (CW_∞) = 1.71, 1.69, and 1.63 for both sexes, males, and females by using asymptotic length. Also, Φ (W_∞) = 1.06, 1.05, and 0.98 for both sexes, males, and females by using asymptotic weight.

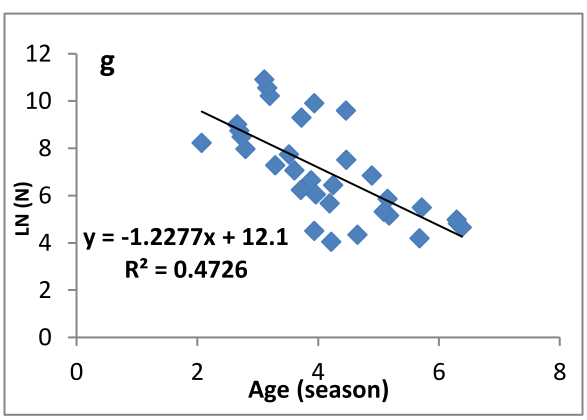
Table 3. Constants of von Bertalanffy growth parameters of *P. pelagicus* in the eastern Mediterranean Sea.

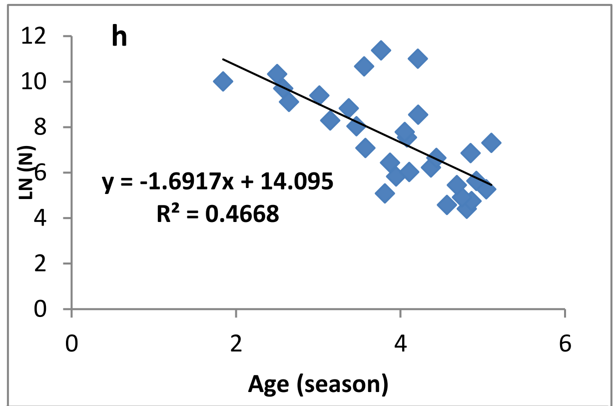
Constant	Both sexes	*Males*	*Females*
CW_∞	17.68 cm	17.82 cm	17.41
K	0.17	0.15	0.14
t_0	-1.19 yr^{-1}	-1.28 yr^{-1}	-1.41 yr^{-1}
W_∞	576.08 gm	626.50 gm	551.15 gm

3.4. Population dynamics

3.4.1. Mortality coefficient

Total mortality coefficient (Z), defined as the total loss by natural and fishing death of individuals. Instantaneous total mortality calculated by the linearized length converted catch curve, were Z = 1.41, 1.23, and 1.69 per year for all individuals, males, and females, respectively (figure g, h, and i). Instantaneous natural mortality found M = 0.56, 0.53, and 0.51 per year for all individuals, males, and females, respectively, versus fishing mortality F = 0.85, 0.70, and 1.18 per year for all individuals, males, and females, respectively.





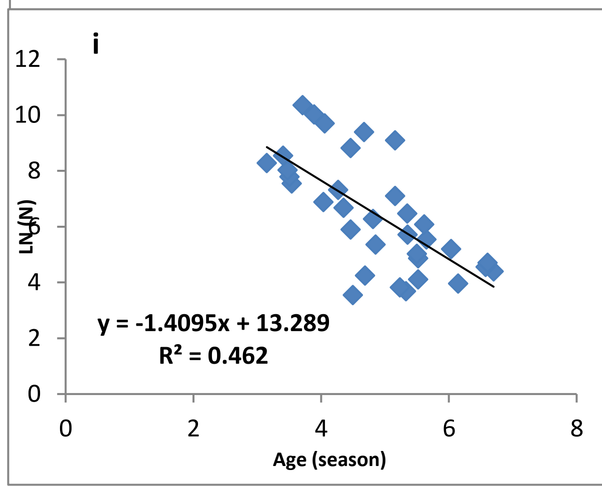


fig. (g, h, and i). Total mortality "Z" from linearized length converted catch curve of *P. pelagicus* in the eastern Mediterranean Sea. *g)* males, *h)* females, and *i)* all individuals.

3.4.2. Exploitation and Survival rate

The current estimated exploitation rate of the *P. pelagicus* population in the eastern Mediterranean Sea was 0.60 per year (E = 60 %) for all individuals, where it more than the optimum exploitation rate at E = 0.5, suggested by (Gulland, 1971). Exploitation rate was E= 0.57 and 0.70 per year for males and females.

Survival rate (S) of the *P. pelagicus* in the coast of North Sinai was S = 0.24, 0.92, and 0.18 per year for both sexes, males and females, respectively.

3.5. Population management

3.5.1. Length and age at first capture (CWc, tc) is less than the actual value of the fishing mortality F_{pr} = 0.85 per year (figure j).

Table 4. Yield and biomass per recruit (Y/R and B/R) with different fishing levels of *P. pelagicus* in the eastern Mediterranean Sea.

Fishing Mortality	Yield per recruit	Biomass per recruit
0.00	0.000	88.482
0.10	6.949	69.488
0.20	11.342	56.711
0.30	14.289	47.630
0.40	16.359	40.898
0.50	17.869	35.737
0.60	19.003	31.672
0.70	19.877	28.396
0.85*	20.86*	24.51*
0.90	21.119	23.465
1.00	21.569	21.569
2.00	23.598	11.799
3.00	24.212	8.071
4.00	24.489	6.122
5.00	24.642	4.928
6.00	24.737	4.123
7.00	24.802	3.543

4. DISCUSSION

In the present study, 924 of *P. pelagicus* samples 531 are males and 393 females. Carapace width measured and found ranged between 5.5 and 13.5 cm, and total weight found ranged between 29 and 333 gm. The differences in growth rate between males and females resulted from the earlier age at first reproduction of the females. When a crab becomes sexually mature, growth often decreases due to the significant amount of energy used for reproduction (Hartnoll, 1982). The length frequency distribution used to analyze the von Bertalanffy growth parameters CW_∞, K, t_0, and W_∞. Results of these parameters at the present study were compared with previous studies from the different area (table 5). The difference between these values were may be because of different factors affecting the growth parameters because of methods by which crabs were caught in those localities. in addition to ecological and environmental factors affect the growth rate, the growth rate also differs from stock to stock (Afzaal, et al. 2016).

Carapace width at first capture (CWc) calculated by 8.8 cm at which 50% of this length appears in the catch. The present value agrees with El-Kasheif et al., 2021, in Hurghada region, Egypt, where it was CWc= 8.7 cm. The estimation of growth performance index is important for the stock assessment (Pauly and Munro, 1984). During this study, the growth performance index Φ = 1.7, 1.6, and 1.7 for males, females and both sexes. The present value less than with El-Kasheif et al., 2021 were Φ = 2.0 that because of the environmental conditions of the Red Sea waters were suitable for the growth of *P. pelagicus*.

Growth performance values may be different because of the ecological and geological conditions as well as input values of growth parameters (Devaraj, 1981). It is appropriate to estimate the total mortality to provide direct calculation for the fishing mortality coefficient. Instantaneous total mortality coefficient “Z” of the blue swimming crab in the eastern Mediterranean Many authors study the total mortality coefficient in different geographic locations; Josileen and Menon, (2007) Mandapan Coast, India Z= 4.54, 3.03 yr^{-1} for males and females,

Kamrani et al. (2010) Bandar Abas, Iran Z= 2.48, 2.44 yr^{-1} for males and females, Ihsan et al. 2014, Indonesia Z= 2.53, 3.22 yr^{-1} for males and females, Afzaal, et al. (2016) Pakistan, Arabian Sea Z= 4.60 yr^{-1} for both males and females, and El-Kasheif et al. (2021) Hurghada region, Red Sea, Egypt Z= 2.93 yr^{-1} for both males and females.

Differences between total mortality coefficients values at different locations may related to the abundant in region.

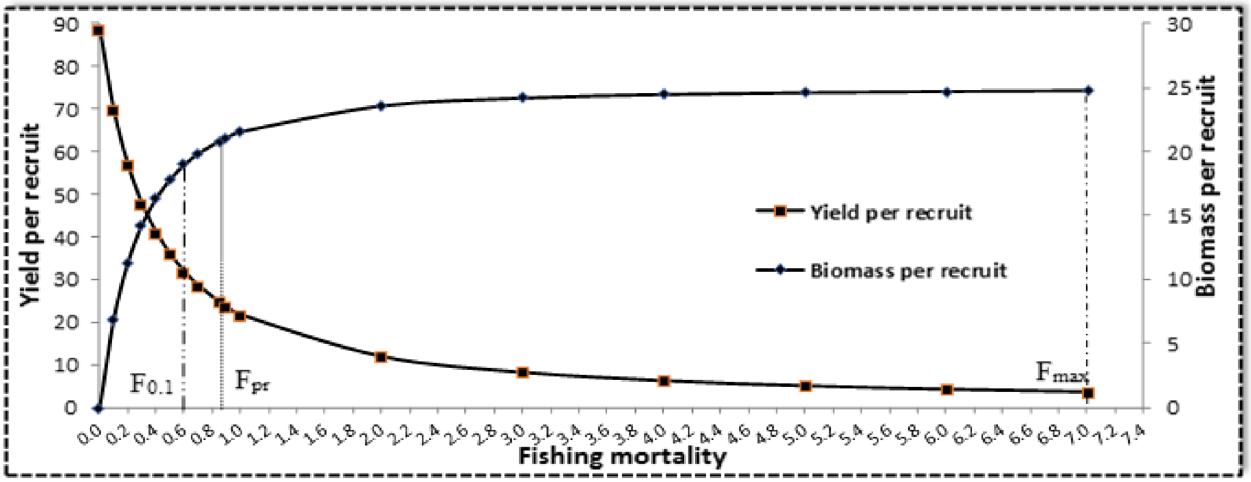


fig. J. Different reference point (F_{pr}, $F_{0.1}$, and F_{max}) of *P. pelagicus* in the eastern Mediterranean Sea.

Table 5. Different values of von Bertalanffy parameters published by many authors on *P. pelagicus* in different geographic locations.

Author	Sex	CW∞	K	t_0	W∞	Location
Sumpton *et al*., 2003	Male	17.5	1.62	-	-	***Australia***
	Female	17.7	1.61	-	-	
Josileen and Menon, 2007	Male	22.3	0.95	-	-	***Mandapan Coast, India***
	Female	19.51	1.0	-	-	
Kamrani, et al., 2010	Male	16.8	1.2	-	-	***Bandar Abas, Iran***
	Female	17.79	1.1	-	-	
Kunsook, 2011	Male	14.26	2.75	-	-	***Thailand***
	Female	16.73	1.3	-	-	
Kembaren et al., 2012	Male	15.9	1.37	-	-	***Indonesia***
	Female	15.4	1.08	-	-	
Hamid and Wardiatno, 2015	Male	15.2	0.93	-	-	***Indonesia***
	Female	17.3	0.68	-	-	
Afzaal, et al., 2016	Both	17.85	1.7	-0.975	-	***Pakistan, Arabian Sea***
Abrenica, et al., 2021	Male	21.65	1.3	-	-	***Danajon Bank, Central Philippines***
	Female	21.4	1.28	-	-	
El-Kasheif, et al., 2021	Both	21.19	0.414	- 0.998	665 gm	***Red Sea, Egypt***
Present Study	Male	17.82	0.15	- 1.28	627 gm	***Eastern Mediterranean***
	Female	17.41	0.14	- 1.41	551 gm	
	Both	17.68	0.17	- 1.19	576 gm	

Estimating natural mortality "M" is one of the most difficult and critical elements of a stock assessment (Harmelin-Vivien, 2007). Natural mortality "M" of *P. pelagicus* in the present study was 0.53, 0.51, and 0.56 year^{-1} for males, females, and both sexes. Many authors study the natural mortality coefficient in different geographic locations; (Josileen and Menon, 2007) Mandapan Coast, India M= 2.76, 2.11 yr^{-1} for males and females, Kamrani et al. (2010) Bandar Abas, Iran M= 1.21, 1.13 yr^{-1} for males and females, Ihsan et al. 2014, Indonesia M= 1.44, 1.27 yr^{-1} for males and females, **Afzaal, et al. (2016)** Pakistan, Arabian Sea M= 1.68 yr^{-1} for both males and females, and El-Kasheif et al. (2021) Hurghada region, Red Sea, Egypt M= 1.28 yr^{-1} for both males and females. The same species may have different natural mortality rates in different areas depending on the density of predators and competitors, whose abundance is influenced by fishing activities (Sparre and Venema, 1998).

Estimates of fish mortality rates are often included in mathematical yield models to predict yield levels obtained under various exploitation scenarios (Al-Beak, 2016). Fishing mortality "F" in the current study was 0.70, 1.18, and 0.85 year^{-1} for males, females, and both sexes. Exploitation rate is the fraction of an age class that caught during the life span of a population exposed to fishing pressure, the exploitation rate was 0.57, 0.70, and 0.60 for males, females, and both sexes. Many authors study the exploitation rate; Josileen and Menon, 2007, Mandapan Coast, India E= 0.54, 0.52 for males and females, Kamrani et al. 2010, Bandar Abas, Iran E= 0.51, 0.54 for males and females, Ihsan et al. 2014, Indonesia E= 0.43, 0.60 for males and females, Afzaal, et al. 2016, Pakistan, Arabian Sea E= 0.63 for both males and females, and El-Kasheif et al. 2021, Hurghada region, Red Sea, Egypt E= 0.65 for both males and females. This study shows overexploitation on the *P. pelagicus* fishery on the eastern Mediterranean Sea by trawls and trammel net vessels. Patterson, 1992, stated that the exploitation rate should not be greater than 0.4 for the sustainability of the resource.

Calculating Biological reference points $F_{present}$, $F_{0.1}$, and F_{max} provide convenient and good background for the fisheries status of the blue swimming crab in eastern Mediterranean Sea. During this study, we found the fishing mortality the actual value of the fishing mortality F_{pr} is more than the target reference point $F_{0.1}$ of the blue swimming crab, but less than F_{max} that attain the maximum Y/R. The actual value of the fishing mortality F_{pr} shows growth of the overfishing on *P. pelagicus* stock. Current fishing mortality F_{pr} values are agreeing with Afzaal, et al. 2016, which found F_{pr} was greater than $F_{0.1}$ and F_{max} of the blue swimming crab.

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