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Population structure and growth aspects of blue swimming crab, *Portunus pelagicus,* in Bardawil Wetland, Egypt

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ABSTRACT

Based on the growth and population variables, the present study was achieved to evaluate the current status of *Portunus pelagicus* in Bardawil Wetland, Egypt, providing a basis for sustainable development in the fishery sector. About 4065 specimens of *Portunus pelagicus* were collected from the catch of trammel net, with a carapace width of 4.2 to 15.6 cm, most of which were medium sized. The carapace width-weight relationship clarified a positive allometric growth pattern. The overall mean value of the condition factor (5.3) revealed a good condition and suitable habitat. The estimated sex ratio was 1:1.05 for males and females, respectively, which varied insignificantly from the expected ratio of 1:1 (X^2, $P > 0.05$). Three age groups (0^+, 1^+ and 2^+ year) were estimated in which each age group individuals constituted about 11.7, 82.7 and 5.5% of the population, respectively. Von Bertalanffy growth parameters were CW_∞ = 16.6cm, K = 1.4 y-1, and t_0 = - 0.918. The 1st capture (CWc) was detected with a carapace width of 7.80 cm. 4.68 y^{-1}, 2.25 y^{-1} and 2.43 y^{-1} were the estimated values of total (Z), natural (M) and fishing mortality, respectively. The highest value of fishing mortality compared to the biological reference points; F_{opt}= 1.125 and F_{limit}= 1.50 y^{-1}; indicates overexploitation, which was confirmed by the exploitation rate of 0.57. The predominance of *Portunus pelagicus* may refer to the leak presence of natural predators, which are heavily exploited. Restoring the biological balance is an urgently required step.

INTRODUCTION

Blue swimming crab, *Portunus pelagicus*, is the most popular species of crabs for consumption on the Atlantic coasts, Australia, the northern Indian Ocean and the Red Sea **(Lai *et al*., 2010)**. They reached the eastern Mediterranean by migrating via the Suez Canal **(Al-Mohanna & Subrahmanyam, 2001)**. They are crustaceans belonging to the family Portunidae; populating in estuaries and coastal lagoons **(Williams, 1981)**. The flat shape of the hind legs makes it swim with high efficiency. Males can grow up to 25cm for the carapace width, although females never reach this size **(FFS, 2011)**. Its global production increased from 174 thousand tons before 2010 to 298 thousand tons currently estimated **(FAO, 2020)**. Due to its high price and the increase in global demand, it has been cultured in Asia during the mid-nineties **(Romano & Zeng, 2008)**, where China is the largest producer of it and the United States is the largest market for its global import **(Junaidi *et al*., 2019)**.

Concerning Egypt, Blue swimming crab was found in the Red Sea **(Abbas *et al*., 2016)**, the Mediterranean and many northern lakes, with annual production of 8671 tons **(GAFRD, 2020)**. It is receiving great demand from the local consumer, especially females with ripe ovaries, which exceeds twice the male's price.

The fishermen are increasing the fishing effort on this species to meet the increasing demand. The accurate result is an increase in the current production, but how long will the increase continue, of course not for a long term, as a result of the stock depletion, the decrease in mature individuals and the decrease in length at the first capture. In fact, production decline is inevitable. Blue swimming crab in the Egyptian coasts was the main subject of many previous studies, focused on studying stock assessment and fisheries management **(Mehanna, 2005; Mehana & Haggag, 2007)**, population dynamics **(Emam, 2010; Abdel Razek *et al*., 2016**; **Ahmed, 2019)**, age determination **(Kilada & Ibrahim, 2016)** and reproductive characteristics **(Abdel Razek *et al*., 2019; Sabrah *et al*., 2020)**.

On the other hand, the Bardawil Lake is a Mediterranean coastal lagoon of North Sinai, characterized by hypersalinity, sandy bottom, as well as its distance from pollution sources and wastewater. With a length of 80km and a width of 14km, the area of Lake Bardawil is about 650km^2 with a maximum depth of 3m **(Elshinnawy & Almaliki, 2021)**. The eastern sector of Lake Bardawil, Zaranik, was subjected to the Ramsar convention for the conservation of wetlands. Blue swimming crabs have a great importance in the Bardawil Lake, producing 1138 tons annually, which represents 35% of the lake's production and 13% of the total Egyptian catch of crabs **(GAFRD, 2020)**.

The main purpose of the current study was to shed light on some biological aspects and explore the population characteristics of blue swimming crabs in the Bardawil Lake. This would contribute to a balanced catch management to achieve the highest production and preserve the stock.

MATERIALS AND METHODS

1. Sampling and study area

Trammel net is a major and widespread fishing gear in Lake Bardawil, and it is considered the main craft of crab fishing in that region. Sampling of blue swimming crab was monthly carried out from several landing sites of trammel fishing vessels covering the eastern and the western lobs of Lake Bardawil (Fig. 1). During the fishing season of 2019, 4065 random individuals of blue swimming crabs were collected over 8 consecutive months, due to the authorities' decision to prevent fishing activities in the Lake for 3 months, extending from January to March.

Each individual was sexed according to morphological examination, male or female, and then the sex ratio was estimated. Carapace length (CL) and carapace width (CW) were measured to the nearest 0.1cm, and the total body weight was recorded to the nearest 0.1g.

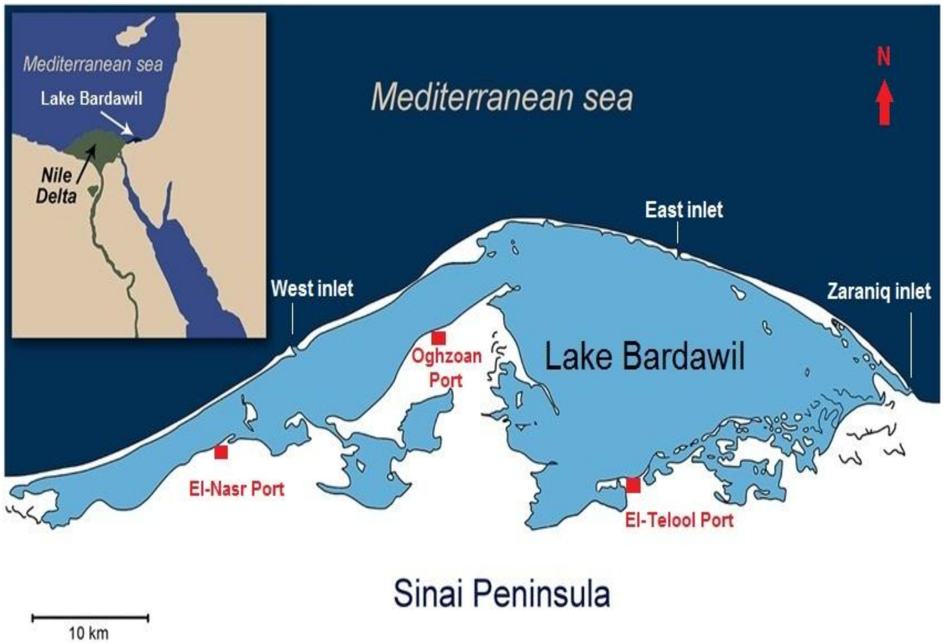

Fig. 1. Map showing Lake Bardawil, landing sites and the lake-sea connections

2. Age and growth aspects

Based on the carapace width (CW), the specimens of blue swimming crab were grouped to 1.0cm intervals, then (CW) the frequency distribution was estimated as a percentage.

Fulton's condition factor (K) was calculated according to the following equation;

$$K= 100W/CW^3 \qquad \textbf{(Ricker, 1975)}$$

Where, (K): condition factor, (W): total weight in gram and (CW): carapace width in cm.

Carapace width (CW)-weight (W) relationship (CWWR) was estimated according to the following allometric equation:

$$W= a\ CW^b \qquad \textbf{(Pauly, 1984)}$$

Where, (W): total weight in gram, (CW): carapace width in cm, (a): regression constant, and (b): the allometric growth coefficient (exponent value).

Carapace length (CL)-weight (W) relationship (CLWR) was estimated according to the following allometric equation:

$$W= a\ CL^b \qquad \textbf{(Pauly, 1984)}$$

Where, (W): total weight in gram, (CL): carapace length in cm, (a): regression constant, and (b) the allometric growth coefficient (exponent value).

ICLARM's FiSAT-II software provided models, which used (CW) frequency distribution for age, growth and population structure as follows:

Age estimation was evaluated according to **Bhattacharya (1967)**. For Von Bertalanffy parameters, the asymptotic carapace width ($CW\infty$) and growth coefficient (K) were estimated by applying (ELEFAN) I according to **Gayanilo *et al*. (2005)**.

The growth performance index **(Ø)** was determined according to **Pauly (1983)** as follows:

$$Ø = \log K + 2*\log CW_\infty$$

Where, (CW_∞) is the asymptotic carapace width and (K) is growth coefficient.

3. Population structure

- Total mortality (Z) and natural mortality (M) were estimated according to **Pauly (1983)**. Fishing mortality (F) was estimated by subtracting the value of natural mortality (M) from the value of total mortality (Z) as follows:

$$F = Z - M$$

- Length at first capture (Lc) was obtained by plotting the curve for the probability of capture by length **(Pauly, 1984)**.
- The exploitation rate (E) was estimated according to **Cushing (1968)** as follows:

$$E = F / Z$$

- For the biological reference point (BRP's), fishing mortality rate with target (F_{opt}) and fishing mortality limit (F_{limit}) were calculated using the two formulas described by **Patterson (1992)** as follows:

$$F_{opt} = 0.5\ M \ \&\ F_{limit} = 2 / 3\ M$$

- The carapace width that generates optimum yield per recruit (CW_{opt}) was estimated according to **Beverton (1992)** as follows:

$$CW_{opt} = CW_\infty * \{3 / (3 + M/K)\}$$

- Relative yield per recruit Y'/R and relative biomass per recruit B'/R were calculated using the model of **Beverton & Holt (1956)** with respect to the knife -edge method, provided in FISAT-II software.

4. Statistical analysis

The descriptive statistics, chi-square test (for sex ratio), standard deviation and regression analysis were carried out by using SPSS program version 16.0.

RESULTS

1. Catch composition of Lake Bardawil

The annual production of Lake Bardawil was about 3215 tons of different fish species **(GAFRD, 2020)**. The specific production of the lake indicates that crabs were the most productive species, since its production exceeds 35% of the total catch. Mullet, shrimp and seabream also occupied an advanced position, representing 25%, 12% and 11% of the annual catch, respectively. There were many species of high economic value, viz. groupers, seabass, sole and meager, which vary in there percentage of the annual catch and represented 9%, 6%, 4% and 0.1%, respectively (Fig. 2).

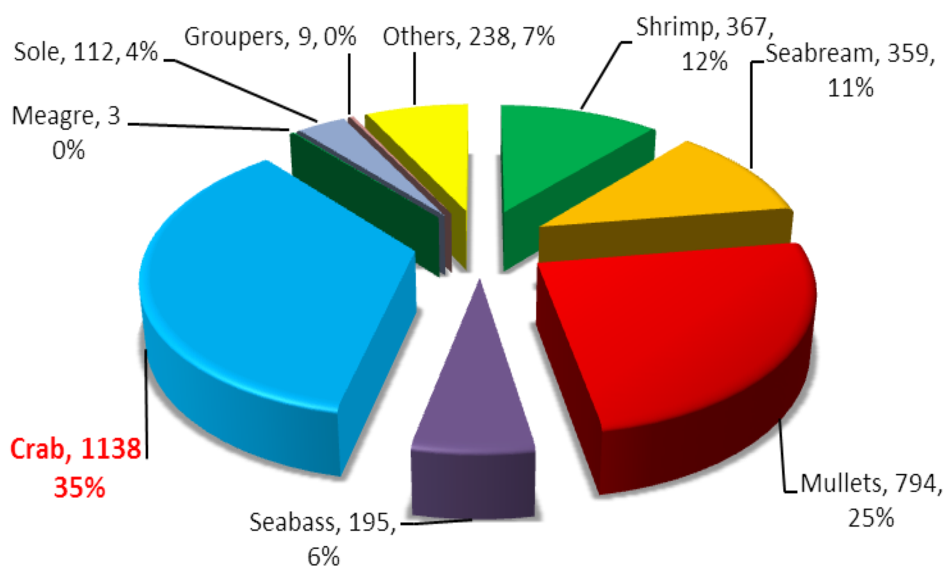

Fig. 2. The annual trend of catch by fish groups from Lake **Bardawil (GAFRD, 2020)**

2. Morphometric relationships

2.1. Carapace width (CW) frequency distribution

Depending on the carapace width (CW), the frequency distribution of blue swimming crab in Lake Bardawil is observed in Fig. (3). The total yield of blue swimming crab was represented by carapace widths ranging from 4.2 to 15.6 cm. It was noticeable that medium sizes were dominant for *Portunus pelagicus* population, where carapace width groups 9, 10, and 8 represented 27%, 19.5% and 16.2% of the catch, respectively.

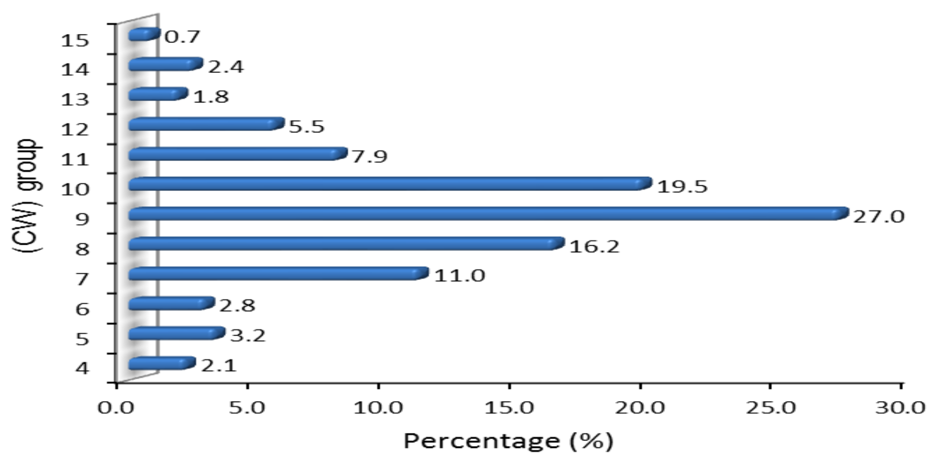

Fig. 3. Carapace width (CW) frequency distribution of Blue swimming crab in Lake Bardawil

2.2. Carapace width- weight (CW-W) relationship

Carapace width-weight (CW-W) relationships for males, females and combined sexes of *Portunus pelagicus* were explained by the following equations:

$\mathbf{W= 0.0546\ CW^{3.137}}$ (R^2= 0.9427) for males;

$\mathbf{W= 0.0492\ CW^{3.194}}$ (R^2= 0.9377) for female, and

W= 0.0522 CW $^{3.162}$ (R^2= 0.9377) for combined sexes.
Where, W: weight (g), CW: Carapace width (cm), and R^2: coefficient of determination. The graphical representations of CW-W relationships are shown in Fig. (4).

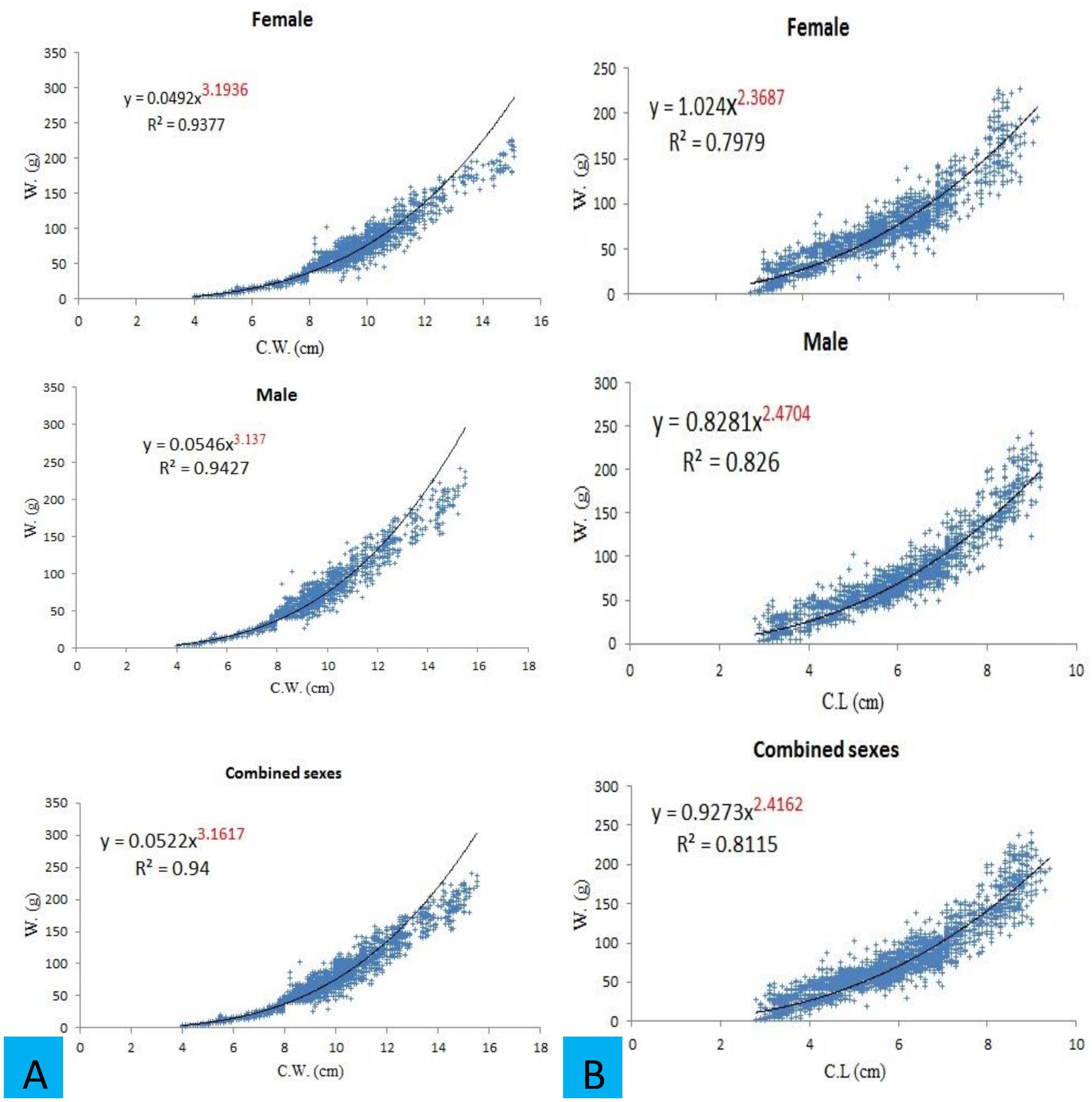

Fig. 4. Morphometric relationship of CW-W (A) and CL-W (B) of *P. pelagicus* in Lake Bardawil

2.3. Carapace length-weight (CL-W) relationship

The morphometric relationships of carapace length and total body weight were expressed by the following equations:
W= 0.828 CL $^{2.4704}$ (R^2= 0.826) for males;
W= 1.024 CL $^{2.3687}$ (R^2= 0.798) for female, and
W= 0.927 CL $^{2.4162}$ (R^2= 0.8115) for combined sexes.
Where, W: weight (g), CL: Carapace length (cm), and R^2: coefficient of determination. The relationship is illustrated in Fig. (4).

2.4. Condition factor (K)

Cosidering carapace width groups, values of condition factor varied significantly (ANOVA, $P<0.05$), where the mean values of females varied from 3.6 (CW group 4) to 5.7 (CW group 8), 3.7 (CW group 3), and 6.3 (CW group 8) for males **(Fig. 5)**. Based on the variety of months, a highly significant correlation was detected for both sexes in the monthly variation in (K) mean values. Except for a peak in July, the curve line of (K) was stable, following the same pattern for both sexes (Fig. 6). Generally; the overall (K) mean value was 5.3, and the medium sizes of *P. pelagicus* recorded the highest mean values of condition factor.

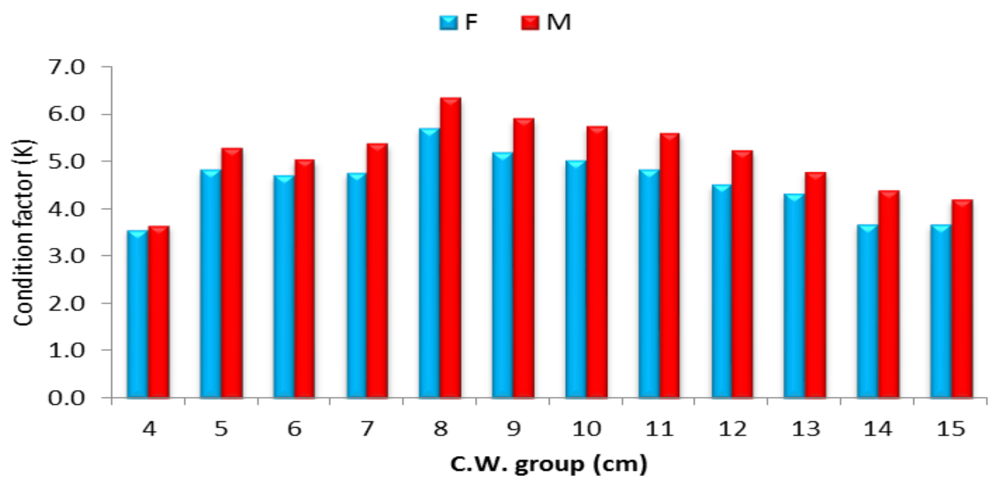

Fig. 5. Variation in condition factor (K) according to (CW) groups of *P. pelagicus* in Lake Bardawil

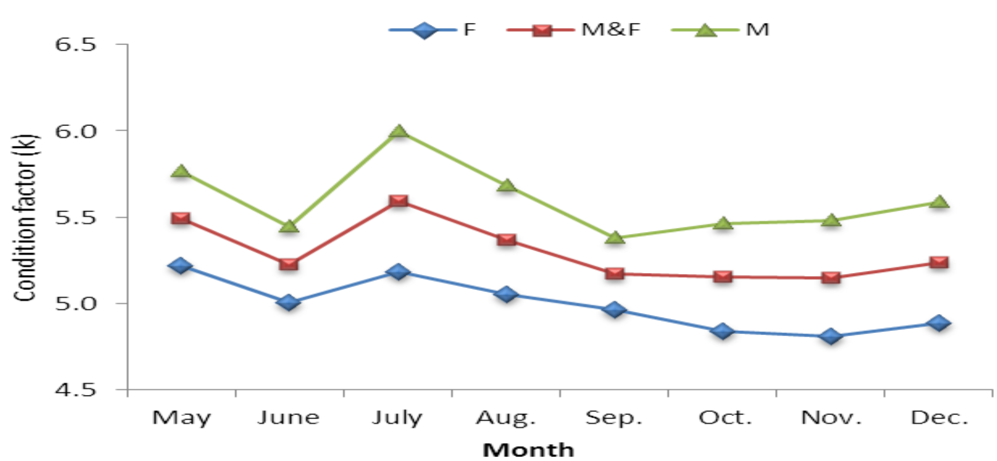

Fig. 6. Monthly variations in mean values of condition factor (K) of *P. pelagicus* in Lake Bardawil.

3. Sex ratio

The data obtained from the estimated sex ratio revealed that, the overall ratio of males to females was (1:1.05), which varied insignificantly from the expected ratio of 1:1 (X^2, $P > 0.05$). The estimated sex ratio for each (CW) class revealed that the absolute dominance of males in the large sizes; 12, 13, 14 and 15 of (CW) group; while the ratio was equal and sometimes recorded a slight increase in females of the other sizes categories (Fig. 7). With respect to months, females were slightly dominant during the period from May to August, then the ratio gradually tended to males predominance in September and October, attaining its highest percentage (60.2) in November (Fig. 8).

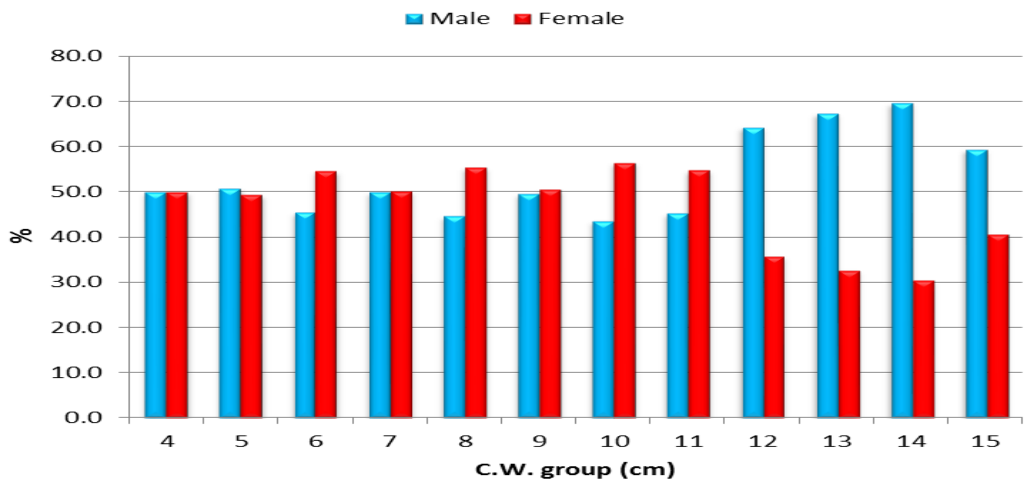

Fig. 7. Frequency distribution of males and females of *P. pelagicus* of the (CW) group

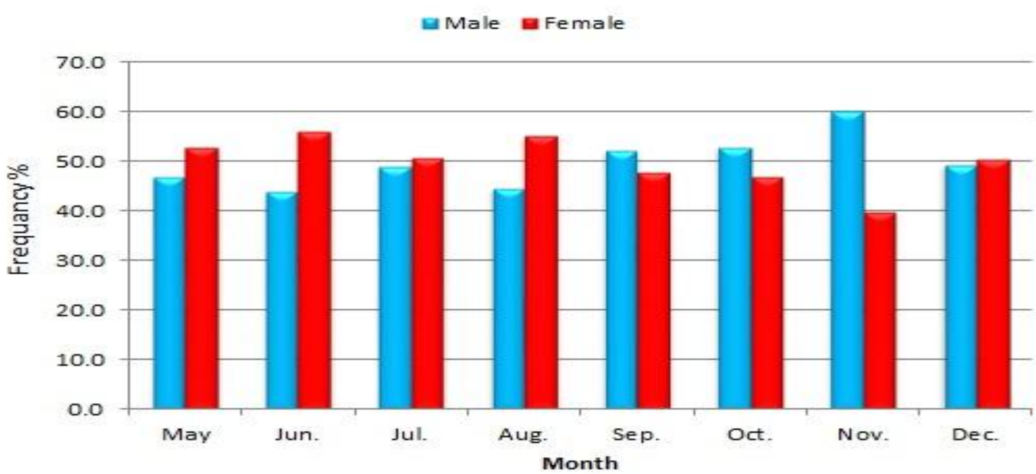

Fig. 8. Monthly variation in sex frequency of *P. pelagicus* in Lake Bardawil

4. Age and growth parameters

The age of blue swimming crab in Lake Bardawil was estimated, and the data revealed that, the population was consisted of 3 age groups, 0^+, 1^+ and 2^+, where individuals of each age group represented about 11.7, 82.7 and 5.5% of the population, respectively (Fig. 9). The mean (CW±S.D.) of each age group was 5.26 ± 1.34, 9.18 ± 1.18 and 13.75 ± 0.81cm, respectively (Table 1).

Table 1. Mean carapace width (CW) at age estimated from carapace width frequency distribution

Age group	Mean CW (cm)	Population	Frequency	S.D.	S.I.
0	5.26	478	11.7	1.34	n.a
1	9.18	3363	82.7	1.18	2.430
2	13.75	224	5.5	0.81	2.500

The estimated growth parameters related to Von Bertalanffy were CW_∞ = 16.6cm, K = 1.4 y^{-1}, and t_0 = - 0.918. The overall growth curve is shown in Fig. (10). The growth performance index (Ø) was estimated for 2.586.

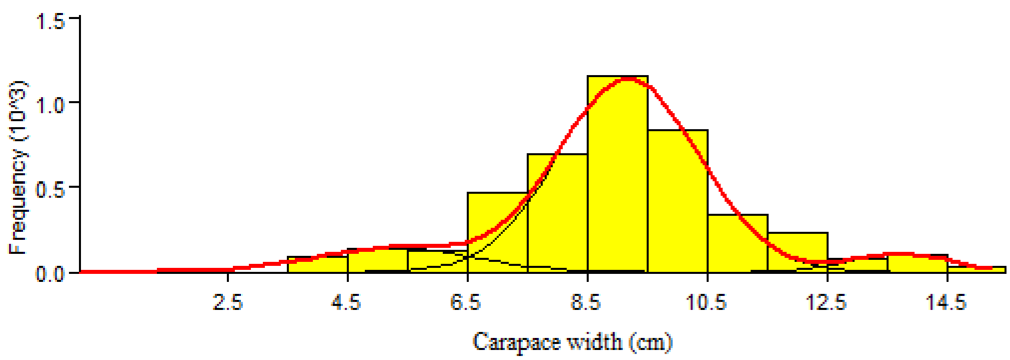

Fig. 9. The decomposition of the carapace width frequency distribution of *Portunus pelagicus*

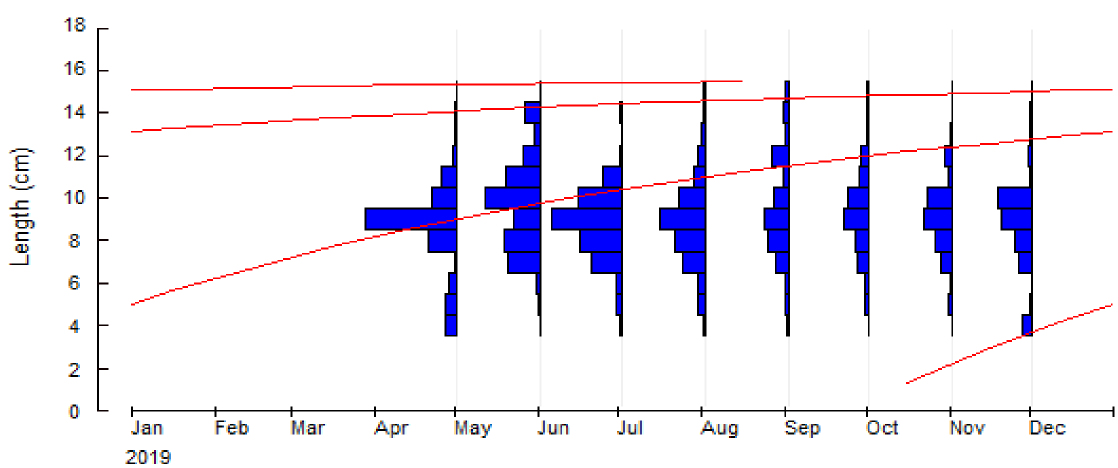

Fig. 10. Carapace width (cm) frequency and Von Bertalanffy growth curve of *P. pelagicus* in Lake Bardawil

5. Demographic aspects

5.1. Mortality

The carapace width frequency was used and the length converted catch curve was applied for estimating the rate of mortality items. Total mortality (Z) was elicited and was 4.68 y^{-1}, in addition to 2.25 y^{-1} and 2.43 y^{-1} for natural (M) and fishing (F) mortality, respectively (Fig. 11). Biological reference points were F_{opt} = 1.125y^{-1} and F_{max} = 1.50 y^{-1}.

5.2. Carapace width at first capture (CWc)

The carapace width at first capture is the width at which 50% of the population has already fallen under the threat of fishing gears. The probability of capture was extrapolated as a function of (CW) converted catch curve. CW_{25} and CW_{75} were 6.96 and 8.92cm, respectively. With a carapace width of 7.80 cm, *Portunus pelagicus* in Lake Bardawil recorded its CW_{50} (Fig. 12). The carapace width optimum (CW_{opt}) was calculated as 10.81cm.

6. Fishery assessment

The yield/ recruit model was dependable as a basic framework for data processing and preparation of basic outputs for assessing the fishery of *Portunus pelagicus*. The analyzed data and the outputs of yield/ recruit and yield / biomass are presented in Fig. (13). CWc / CW∞ and M/K ratio were calculated, and the values of 0.450 and 1.60 were reported, respectively. Series of exploitation levels were estimated, where E_{max} = 0.666, $E_{0.1}$= 0.570 and $E_{0.5}$= 0.348, expressing maximum, present and optimum yield, respectively. Biological reference points were estimated, where F_{opt} = 1.125 year^{-1} (the target), F_{limit} = 1.50 year^{-1} (the maximum) and F_{cur} = 2.43 year^{-1} (the current). The virtual population analysis (VPA) was applied and the data are exhibited in Fig. (13).

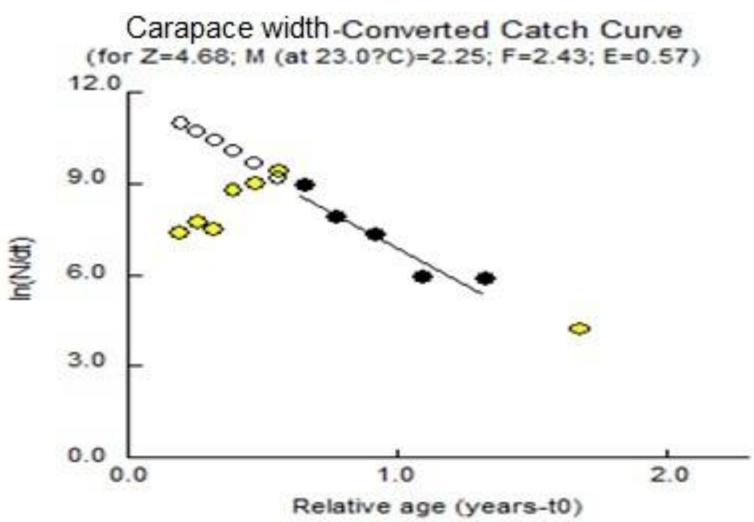

Fig. 11. (CW) converted catch curve and mortality items of *Portunus pelagicus* in Lake Bardawil

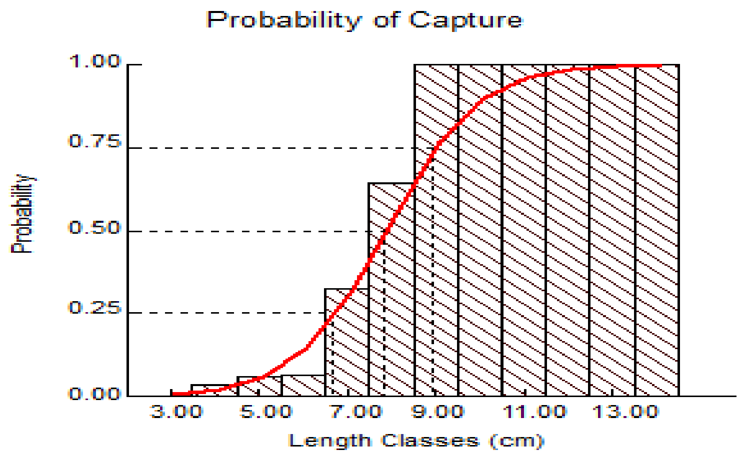

Fig. 12. The probability of capture and the estimated (CW_{50}) of *Portunus pelagicus* in Lake Bardawil

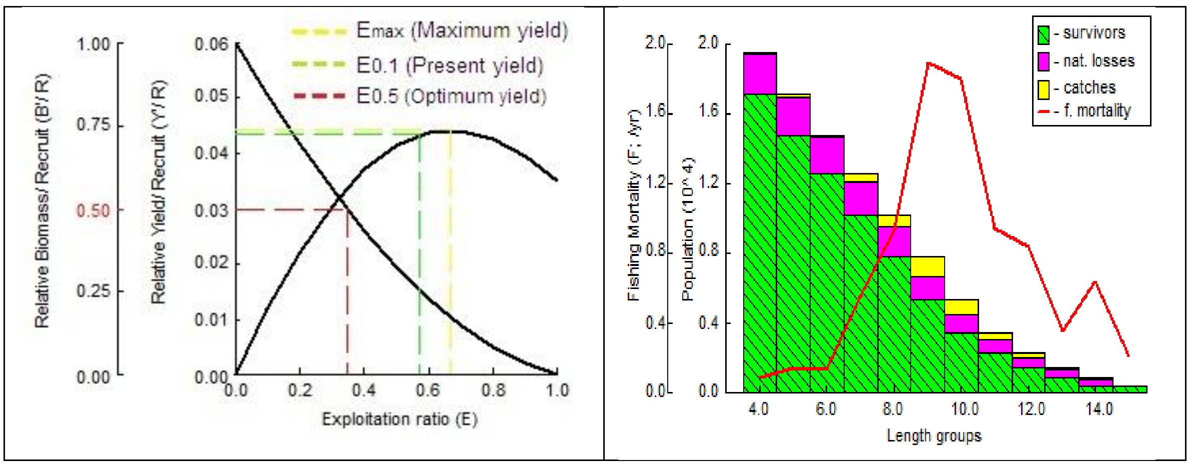

Fig. 13. Exploitation rate, the yield per recruit and virtual population analysis (VPA) of *Portunus pelagicus* in Lake Bardawil

DISCUSSION

Lake Bardawil is considered as a special features fishing area, due to the presence of many marine species of high economic value and superior quality. Recent statistics indicate that crustaceans have the largest share in the total catch of Lake Bardawil; about 47% of the total catch, where crabs and shrimp represent about 35% and 12% of the annual catch, respectively **(GAFRD, 2020)**. Radical changes in species composition and the relative abundance have occurred during the last fifty years, where the annual catch of some marine species declined sharply, especially gilthead seabream, which represented 11% of the total catch, compared to 70% and 48.5% during seventies and eighties, respectively **(GAFRD, 2008)**. Most crustaceans versus some marine fish species in Lake Bardawil were reported by **Mehanna (2006)** and **Gabr (2015)** who confirmed the widespread presence of crustaceans in Bardawil Lagoon, with the highest percentage of the lagoon production. The same observation was reported in the study of **El-Aiatt *et al.* (2019)** who found that, crabs constitute about 42% of the total landing species in Lake Bardawil with a decline in other marine species. During 1969-1971, a complete block of the 3 lake-sea connections occurred, causing a violent rise in water salinity, reaching 120 ‰ **(Ben-Tuvia, 1979)**. Despite that, gilthead seabream was still in absolute dominance with a negligible percentage of crustaceans **(Sadek & Ameran, 1984)**. Based on the foregoing, the co-authors believed that the environmental conditions are innocent of these sharp changes in species predominance, and the main reason is the illegal fishing practices, which deplete the stocks of these fish species in the hope of exporting them to Europe and obtaining profits. This situation made the crustaceans thrive dramatically as a result of the biological imbalance. **Mehanna (2006)** suggested that the shift in crustaceans' predominance versus the depletion of marine fish species may be due to the extensive use of illegal fishing gears, which target specific species.

The size structure of blue swimming crab in Lake Bardawil was subjected to scrutiny in the present study. By examining 4291 individuals, it was found that individuals belonging to the sup-medium carapace width groups (9, 10 and 8cm) were the dominant ones, representing 27%, 19.5% and 16.2%, respectively. The larger sizes (> (CW) 10cm) were subjected to a sharp decline, and down to 0.7% for the highest size category. Ahmed (2019) reported that the blue swimming crab in Lake Bardawil represented by (CW) ranged from 4.7 to 13.4cm, the majority of which were medium-sized (8, 9 and 10cm of carapace width groups). With a maximum (CW) of 14cm and frequency's peak detected in 9cm of carapace width group, the same species was found in the Red Sea **(El-Kasheif *et al.*, 2021)**. The blue swimming crab in Western Australia continues growing, recording a carapace up to 25cm in width, and up to 1kg of weight **(FFS, 2011)**. Variations in crab's size may be due to habitat ecology, food availability and fishing effort, which are key factors that vary by location **(Atar & Seçer, 2003)**.

Morphometric measurements of body dimensions and their relationship to weight were carried out to investigate the growth pattern. Carapace width-weight relationship was estimated for *Portunus pelagicus*, where "b" values were 3.137, 3.194 and 3.162 for males, females and combined sexes, respectively, expressing a slight positive allometric growth pattern. This means that *Portunus pelagicus* in Lake Bardawil becomes heavier for its weight than its growth in carapace width. On the other hand, "b" values of the carapace length-weight relationship indicate that the increase in weight exceeded the rate of carapace length increment. In general, the linear relationship proves the correlation of weight increment with the length and width of the carapace, although the weight is more related to the carapace width than to its length. The high values of the "R^2" coefficient indicate perfectly fit prediction equations. The positive allometric growth for *Portunus pelagicus* was reported in the studies of **Josileen (2011)** in India, **Pristya *et al*. (2015)** in Indonesia and **El-Kasheif *et al.* (2021)** in the Red Sea. Nevertheless, **Prihatiningsih and Wagiyo (2009)** and **Panggabean *et al*. (2018)** reported a negative allometric growth pattern. Differences in growth patterns and morphometric dimensions may be attributed to ecological and genetic differences among populations **(Abinawanto *et al*., 2018)**.

Concerning the condition factor (K) in the present study, the higher values for males compared to females were consistent with multiple studies in several regions **(Rohmayani, *et al*., 2018; Astuti, *et al*., 2020** and **El-Kasheif *et al.*, 2021)**. The present highest values of (K) were found to be aligned with the highest percentage of the full stomach of *Portunus pelagicus*, which was recorded during spring extension to early summer **(Abdel Razek, 1988)**. In addition to the negative correlation with gonadosomatic index (GSI) values, recorded by **Abdel Razek *et al*. (2006)**, who reported a peak of (GSI) in August which associated with our descent in (k) value from the peak. Variation of (K) values may be attributed to ecological variables, food availability and gonadal development **(Froese, 2006** and **Dubey *et al*., 2014)**. According to (CW) groups, the medium sizes were found to be in the best condition, compared to the lower and the upper sizes.

Sex ratio of crustaceans is affected by several variables. The disparity in sex ratio could be influenced by migration, fishing gears and extreme seasons **(Sara *et al*., 2010)**. The predominance of males in the big sizes; which were observed in the present study; may be attributed to its higher growth rate and that associated with the finding of **Xiao & Kumar (2004)** for blue swimming crap. On the other hand, reproductive activities and maturation may also be affecting the monthly variation in sex ratio, where the peak of (GSI); reported by **Abdel Razek *et al*. (2006)**; was followed by an increase in the proportion of males in the present study. Crab's behavior during spawning was studied and its role in the ratio variations between sexes was confirmed **(Kumar *et al*., 2000)**. The overall sex ratio in the present study matches with the balanced ratio which was reported in several regions **(Dineshbabu *et al*., 2008; Nitiratsuwan *et al*., 2013; Nurdin *et al*., 2016** and **Ahmed, 2019)**.

Concerning age and growth, blue swimming crab in Lake Bardawil was represented by 3 age groups, with the highest percentage for the second group (82.7%), which indicated short longevity as most crustaceans. Longevity is one of the fundamental characteristics of stock assessment **(Kangas, 2000)**. There was a wide range for the longevity of blue swimming crab which was clarified during many studies, where it was 2.5 years in India **(Sukumaran & Neelakantan, 1997)**, 3 years in Queensland **(Smith & Sumpton, 1987)**, 5 years in the Red Sea **(El-Kasheif *et al.*, 2021)** and even 9 months in Lake Bardawil, Egypt **(Mehanna & El-Aiatt, 2011)**. Variation in aging and longevity of *Portunus pelagicus* may be related to ecology, the applied methods for estimation, the technique of sampling and exposure to extreme habitat conditions which may be affected (negatively or positively) in specific sizes **(Smith & Sumpton, 1987)**.

Von Bertalanffy parameters; (CW_{∞}) and (K); were estimated and found to be 16.6 cm and 1.4 year $^{-1}$ respectively. These values express the scenario of short longevity and the high growth rate, in addition to the negative value of t_0 (0.918), which confirmed the fast growth during early life stages. According to populations, a variation in growth pattern is a confirmed observation **(Kangas, 2000)**. Similar results were reported by **(Sumpton *et al*., 1994** and **Kamrani *et al*., 2010)**. Comparing with our results, **Mehanna & El-Aiatt (2011)** reported another pattern of growth parameter; CW_{∞}=8.38 and K=2.04 year^{-1}; for the same species in Lake Bardawil, Egypt, which clarifies the negative correlation between (CW_{∞}) and (K). Age, sex, maturation and location are basic variables, its changes will reflect in growth parameters **(Amin *et al*., 2015)**.

The growth performance index (Ǿ) was calculated and the value was found to be 2.59, which suggested a suitable habitat and ecological condition in Lake Bardawil. For the same species, a lower value (2.0) was reported in the Egyptian sector of the Red Sea **(El-Kasheif *et al.*, 2021)** and 2.3 in Lake Bardawil **(Ahmed, 2019)**; compared to a higher value (2.8) of **Afzaal *et al.* (2016)**, which was recorded in Pakistan. Variations in (Ǿ) value were related to changes in salinity, temperature and food availability **(Devaraj, 1981)**.

Carapace width at first capture (CWc) was obtained at (CW) 7.80 cm, which was lower than carapace width at first sexual maturity; 9.1cm **(Ahmed, 2019)**; and also lower than the optimum carapace width (CW_{opt}= 10.81cm) which generate the maximum sustainable yield. These observations suggested the occurrence of overexploitation.

Demographic parameters provided great information related to lifespan **(Osman *et al*., 2019)**. Concerning mortality, a considerable high value was recorded for natural mortality (M= 2.25 year^{-1}), which represents about 48.1% of the total mortality. In the light of the weak presence of predators, European seabass and Gilthead seabream, the high value of natural mortality may be attributed to ecological factors and the hypersalinity in particular, which negatively affected early life stages and juveniles. The larvae of blue swimming crab were dying under treatment of 50 ‰ of salinity **(Ikhwanuddin *et al*., 2016)**. The early stages were very sensitive to salinity and may cause high mortality in addition to the high load in metabolic requirements **(Parado-Estepa & Quinitio, 2011)**. According to the direct relation between (M) and (K) which was observed by **Beverton & Holt (1956)**, the ratio was estimated and the value of 1.6 was reported, which was found to be within the normal range (1-2.5) **(Afzaal *et al*., 2016)**. The estimated fishing mortality (2.43 year^{-1}) absolutely exceeds biological reference points (F_{opt} = 1.125y^{-1} and F_{limit}= 1.50 y^{-1}) in addition to 0.57 for the exploitation rate (E). Virtual population analysis (VPA) indicated that 10 and 9 cm of (CW) groups were facing the highest fishing mortality with values of 3.35 and 3.09 y^{-1}, respectively. Large sizes (14 and 15 cm) were also subjected to high fishing mortality, which recorded 2.74 and 2.43, respectively. Small sizes of blue swimming crab had the least fishing mortality compared to medium and large sizes. A similar case of *Portunus pelagicus* in the Arabian Sea was reported **(Afzaal *et al*., 2016)**. The previous findings confirmed that blue swimming crab in Lake Bardawil was heavily exploited.

Generally, the predominance of blue swimming crab in Lake Bardawil is not due to a lack of fishing effort or exploitation rate. In fact, the major natural predators of crustaceans; European seabass and Gilthead seabream; had been subjected to heavy exploitation in Lake Bardawil **(Ahmed, 2011)**, which created a situation of biological imbalance and gave crustaceans the opportunity to dominate extremely, despite the high exploitation rate. Restoring the lost biological balance is the best solution to rectify this issue by preventing illegal fishing practices that target crustacean's predators. It's unacceptable to recommend an increase in the fishing effort and extra exploitation for blue swimming crab, it's already high.

CONCLUSION

In conclusion, growth aspects of blue swimming crab clarified that Lake Bardawil was an acceptable habitat for this species. Fishery assessment confirmed the absolute abundance, despite the occurrence of overexploitation where sub-adults and medium sizes represent the highest percentage of the population. The heavy exploitation of the natural predators; European seabass and Gilthead seabream; created an imbalanced situation, which caused the extreme domination of crustaceans. The existence of an ambitious plan to develop the catch of natural predators is a required step urgently; increasing the exploitation of crab from the current limit will upset other biological balances, especially since it is currently being caught before reaching sexual maturity.

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