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Poultry Fisheries & Wildlife Sciences

Research Article

Stock Assessment of *Portunus pelagicus* (Linnaeus, 1758) from Southern Arabian Gulf, United Arab Emirates

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ABSTRACT

The growth, mortality and yield per recruit of the blue swimming crab *Portunus pelagicus* were examined from southern Arabian Gulf off the United Arab Emirates between January and December 2021. The FiSAT II software was used to perform the estimate of growth, mortality and exploitation rate. In the present study, asymptotic carapace width CW_∞ and growth coefficient K for males were estimated at 17.01 cm, $0.31y^{-1}$ and for females were 18.27 cm and $0.52y^{-1}$. The growth performance index was calculated at 1.95 and 2.24 for males and females. The overall ratio of males to females was obtained at 1.0: 0.91. Annual instantaneous total mortality (Z) by length converted catch curve was estimated at 0.76, 1.51 and $1.53y^{-1}$ for males, females and combined sexes respectively. The mean rate of natural mortality (M) was evaluated at 0.54 y^{-1} for males, $0.76y^{-1}$ for females and $0.70y^{-1}$ for combined sexes. The carapace width at first capture was estimated for males and females at 10.66 and 11.26 cm respectively. The fishing mortality rate for combined sexes ($F=0.83y^{-1}$) was higher than the precautionary target ($F_{opt}=0.35y^{-1}$ and limit $F_{limit}=0.47y^{-1}$. The carapace width at first sexual maturity for females was estimated at 10.92 cm and was lower than the length at first capture. The recruitment pattern of *P. pelagicus* was continuous throughout the year with peak in June (14.77%). The exploitation rate (E) was calculated at 0.54 and show slightly fishing pressure on the stock.

Keywords: Arabian Gulf; *P. pelagicus*; Growth; Mortality; Stock status

INTRODUCTION

Crabs belong to a group of animals knows as decapods crustaceans. Most of the marine crabs occurring along the Gulf coast belong to the family Portunidae [1]. Blue swimming crab, *Portunus pelagicus* (Linnaeus) is a tropical species belonging to family Portunidae and it is occurring in tropical and temperate coastal and estuarine waters throughout the Indo-West Pacific from Africa to India and extended from Southeast Asia to Australia [2-4]. It can be found in different water depths across many countries in Asia, Australia and Africa [5]. The blue swimming crab is a large commercially valuable crab found within tropical and subtropical regions [6]. The crabs are harvested using traps, beach seine and bottom-set gillnets [7-9]. Over 80 species are encountered under the genus *Portunus* worldwide [10]. The abundance of Portunidae may be differs from one area to another according to the life history of each species which can be vary extremely with various environmental condition [11]. Globally, it was estimated that *P. pelagicus* contributed with about 0.4% (298 thousand MT) of the world total capture production, representing about 5.0% of the global crustacean fisheries [12]. Although the blue swimming crab fishery has a great economic importance in the area, very few studies of this species are available [1,13,14]. The current situation of the fisheries of the United Arab Emirates declared that, *P.pelagicus* has minor components of the demersal species and represents 1.1% of the commercial species caught by traps [15]. Despite the economic significance and the rational exploitation of the crab resources in the United Arab Emirates, the demographic structure of the species remains poorly understood and it necessary to conduct a detailed study on the fishery, growth and stock parameters to understand the impact of these on the stock. Hence, the goal of this study is to estimate the growth, mortality and exploitation rate of blue swimming crab from southern Arabian Gulf off the United Arab Emirates which may be salutary in the management of this species in the area.

MATERIALS AND METHODS

Data collection

Data on carapace width-frequency distribution were collected on monthly basis from four landing sites as representative samples of the Emirates coastal area between January and December 2021 (Figure 1). The Carapace Width (CW) was measured from the tip of the left dorsal spine to the tip of the right one and were

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Received: 17-Nov-2022, Manuscript No. PFW-22-20184; **Editor assigned:** 19-Nov-2022, PreQC No. PFW-22-20184 (PQ); **Reviewed:** 05-Dec-2022, QC No. PFW-22-20184; **Revised:** 12-Dec-2022, Manuscript No. PFW-22-20184 (R); **Published:** 19-Dec-2022, DOI: 10.35248/2375-446X.22.10.215

Citation: Farrag E, Al-Jamali I, Subbaih C, Al-Shaer M (2022) Stock Assessment of *Portunus pelagicus* (Linnaeus, 1758) from Southern Arabian Gulf, United Arab Emirates. Poult Fish Wildl Sci. 10:215

measured in cm. Sexes were separated and the length frequency data were pooled into groups with 3.0 mm length intervals.

Figure 1: Map showing the sampling sites.

Growth parameters

The population dynamics of *P. pelagicus* was carried out by using FiSAT II computer program for fish stock assessment [16]. The von Bertalanffy growth function were used to estimate growth parameters by fitting the length frequency distribution as the formula,

$CW_t = CW_\infty (1\text{-}exp(\text{-}k(t\text{-}t_o)))$

where CW_t is the carapace width in cm, CW_∞ is the carapace asymptotic width in cm, K is the growth coefficient (year), t_o is the theoretical age in years at which length of the fish equal to zero (usually negative) as estimated by the Pauly's equation [17].

$Log(\text{-}t_o) = \text{-}0.3922\text{-}0.2752 \log(L_\infty) \text{-}1.0388 \log(K)$.

The growth performance index (ɷ) was calculated as:

$ɷ=\log_{10}K+2\log_{10} CW_\infty$ [18].

The maximum age (t_{max}) was estimated as:

$t_{max} = 3/k+t_o$ [19]

The size that generates optimum yield per recruit (L_{opt}) was estimated by the empirical equation of Beverton [20]. Carapace width at first maturity was calculated by plotting the logistic curve and the homogeneity of the sex ratio over the years was tested using χ^2 test [21,22].

Mortality and exploitation

The annual instantaneous rate of total mortality (Z) was estimated by length-converted catch curve [19]. The carapace width at first capture was estimated by plotting the cumulative probability of capture against mid-length of class interval; CW_c was taken as corresponding to the cumulative probability at 50%.

Mean natural mortality coefficient (M) was calculated by three different methods [23-25].

$M= 3 \times K/ \{exp \times (t_{max} \times 0.38 \times K)\text{-}1\}$, $M= (1.521/tmass)^{0.72}\text{-}0.155)$ and $Ln(M) = 1.44 - 0.984 \times \ln(t_{max})$

Where, t_{max} is the age of the oldest fish and tmass is the age of massive maturation.

The Fishing mortality (F) was calculated by the equation, F= Z-M and the exploitation ratio (E) was calculated from E= F/Z. This method was used to determine the recruitment pattern in FiSAT [26]. Resource status was evaluated by comparing estimates of the fishing mortality rate with target (F_{opt}) and limit (F_{limit}) biological reference points which were defined as: $F_{opt} = 0.5 \times M$ and $F_{limit} = 2/3M$ [27].

Per-recruit analysis

The Beverton and Holt Yield per recruit were used to estimate YPR model [28]. The biomass per recruit was analysing by the equation [29]. Relative yield per recruit and relative biomass per recruit were estimated according to Beverton and Holt length based method as modified by Pauly and Soriano [30, 31].

The computed exploitation rate was compared with the expected value of $E_{0.5}$ (the exploitation level which will result in a reduction of the unexploited biomass by 50%) and E0.1 (the value of exploitation rate at which marginal increase in Y/R is 10% of its value [29, 32].

RESULTS

Length frequency distribution

Table 1 shows the length frequency distribution parameters of the blue swimming crab, *P. pelagicus* in the coastal area of the United Arab Emirates off the Arabian Gulf.

Sex ratio

The ratio of males to females during a year of the study was obtained as 1.0: 0.91. In the present study, male crabs were captured more frequently than female in all months except in July and August. The variations of sex ratio revealed that, the ratio of males and females is tended to be 1.0: 1.0 in (January, June and December). Chi-square test (χ^2) shows, critical value P is greater than 0.05, so we believe the variables are independent. Studies on the percentage of occurrence of females of advanced ovarian maturity revealed that occurrence of late maturing and matured females were high during February, March and April every year, confirming that peak spawning occurs during these months. The Size at maturity of females was estimated at 10.92 cm and the corresponding age was 1.57 year.

Growth parameters

The ELEFAN method was used to estimate the growth parameters of *P.pelagicus* (Figure 2). The von Bertalanffy growth equation of blue swimming crab was $L_t=17.01(1\text{-}e^{-0.31(t+0.60)})$ for males; $L_t=18.27(1\text{-}e^{-0521(t+035)})$ for females and $L_t=18.27(1\text{-}e^{-0.46(t+0.41)})$ for combined sexes. The optimum length of exploitation L_{opt} estimated was 12.0 cm for the pooled data. The growth performance index (ɷ) of male was 1.95 and that in females was 2.24. Males *P.pelagicus* attained their maximum size (K=0.31 per year) and had a long life span of 9.08 years, while females attained their maximum size (K=0.52 per year) and had life span of 5.42 years. Growth curve was derived for male, female and pooled data of *P. pelagicus* (Figure 3).

The value of L_{opt}/L_∞ calculated was 0.66. There was a general

Table 1: Length frequency distribution parameters of *P. pelagicus*.

Sex	No	CW range (cm)	Mean (cm)	Dominant length group
Male	705	8.7-16.2	12.08	11.4 (7.23%)
Female	643	9.0-17.4	12.52	11.7 (6.84%)
Combined	1348	8.7-17.4	12.29	11.4 (6.68%)

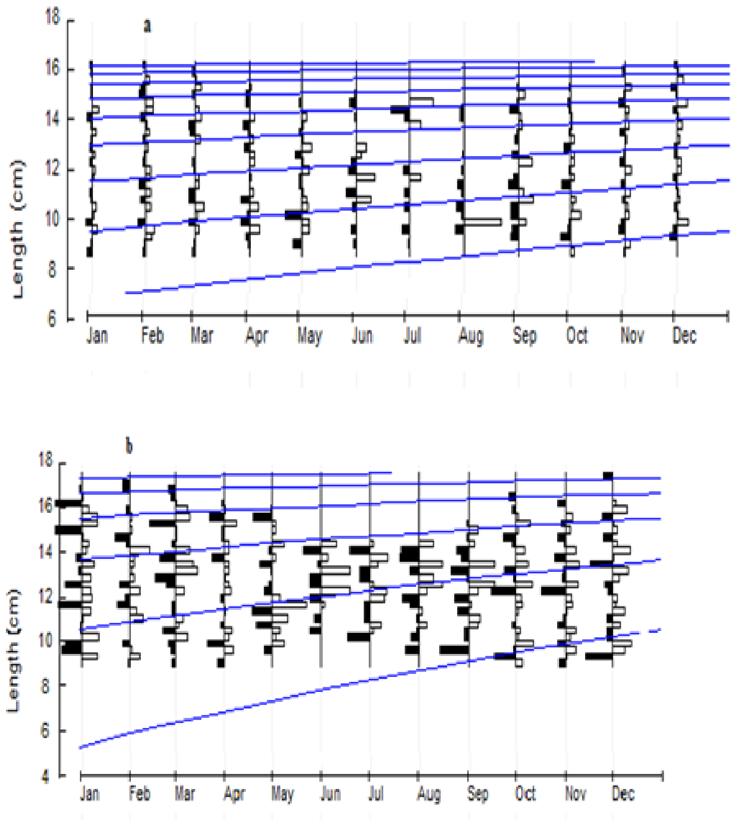

Figure 2: Von Bertalanffy growth curve of males. a) and females. b) *P. pelagicus* fitted by ELEFAN technique.

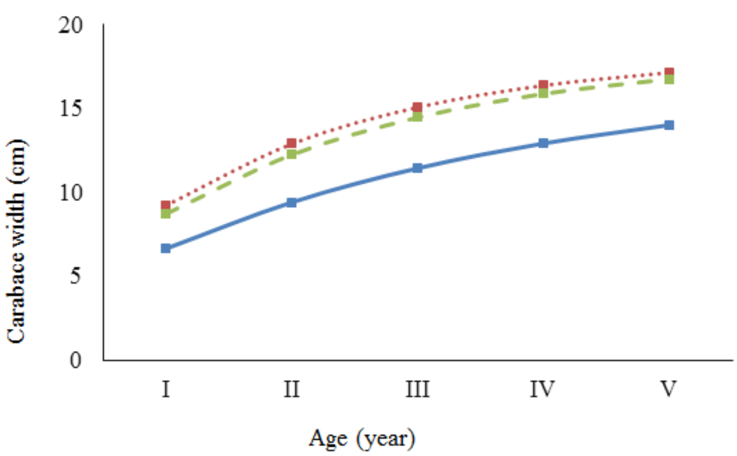

Figure 3: The von Bertalanffy growth function fitted to size-at-age relationship for *P. pelagicus* in the Arabian Gulf. **Note:** (———) represents Male, (·····) represents Female, (— — —) represents combined.

decrease in the growth rate as the age of fish increased. The fish attained lengths of 8.72 cm, 12.24 cm and 14.46 cm at the first, second and third years of life respectively. The M/K value for male and female was 1.76 and 1.46.

Mortality and exploitation

The annual instantaneous rate of the total mortality coefficient (Z) was estimated from the length of converted catch curve at 0.76 and 1.51 year^{1} for males and females respectively (Figures 4 and 5). The mean value of natural mortality (M) of males was 0.54 y^{-1} and that of females was 0.76 y^{-1}. The fishing mortality rate (F) of males and females was 0.22 and 0.75 y^{-1}. The optimum fishing mortality for combined sexes lower than the current level and estimated at 0.35 y^{-1}. The exploitation ratio was obtained at 0.54 for pooled sexes which seemed to be slightly higher than the optimum level of exploitation (E=0.50).

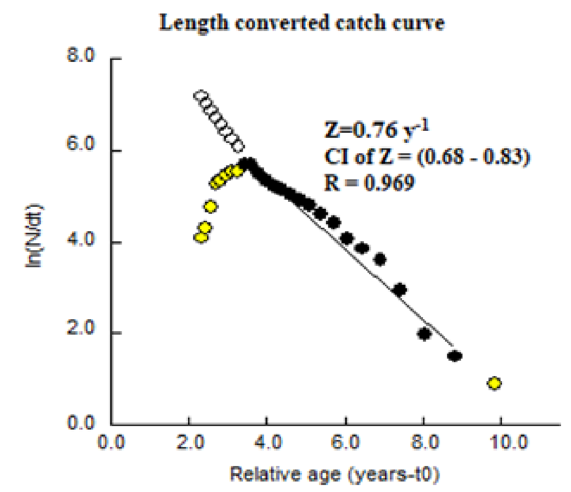

Figure 4: Length converted catch curve of male's *P. pelagicus*.

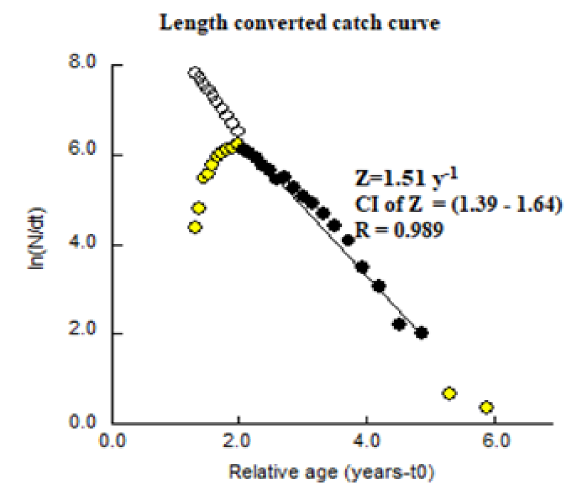

Figure 5: Length converted catch curve of females *P.pelagicus*.

Carabace width at first capture

The mean length of first capture of *P. pelagicus* was estimated as 10.66 and 11.26 of males and females respectively (Figures 6 and 7). The corresponding age at first capture of males was 2.58 years and that in females was 1.49 years. For the data pooled from both sexes, the length at first capture was estimated at 11.15 cm. The value of L_c/L_∞=0.61

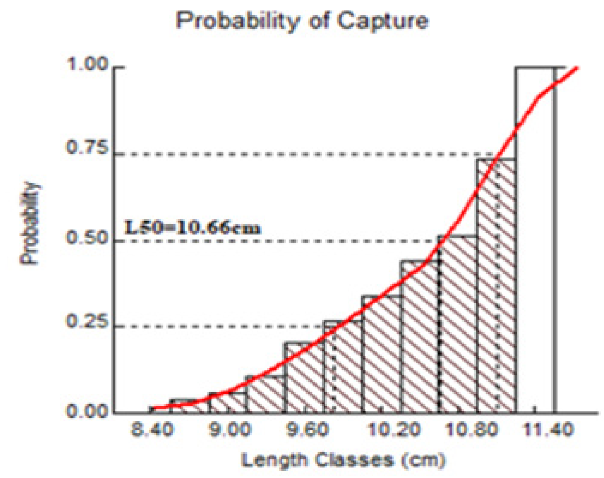

Figure 6: Carapace width at first capture of males *P.pelagicus*.

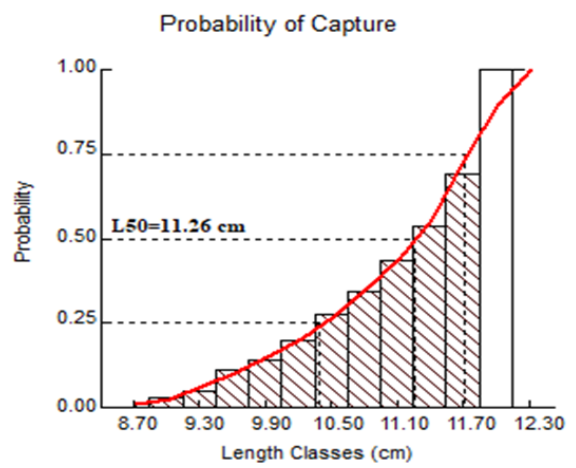

Figure 7: Carapace width at first capture of female's *P. pelagicus*.

Recruitment pattern

The recruitment pattern of *P. pelagicus* from the coastal area of the United Arab Emirates in the Arabian Gulf with two main recruitment peaks. The major peak of recruitment occurred in June with recruitment strength of 14.77%. The length at first recruitment Lr was 8.7 cm and the corresponding age at first recruitment was one year.

Yield per recruit and biomass per recruit

The Y/R and B/R analysis showed that, at the current level of Fishing mortality (F=0.83 year^{1}), The Y/R was 39.72 g and biomass per recruit was 34.42 g (Figure 8). By increasing the fishing morality to the maximum (F=6.0 year^{1}), the Y/R will increase to 47.64 g (19.94%) and the biomass per recruit B/R will decrease to 5.71 g (83.41%).

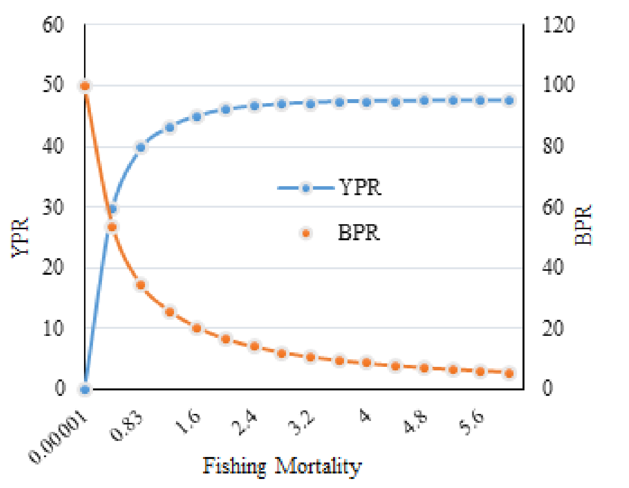

Figure 8: Yield per recruit and biomass per recruit of *P. pelagicus*.
Note: (—■—) represents YPR, (●) represents BPR.

Relative yield per recruit (Y/R) and biomass per recruit (B/R)

From Figure 9, the Beverton and Holt relative yield per recruit model showed that the indices for sustainable yield were 0.40 for optimum sustainable yield ($E_{0.5}$). The current exploitation ratio $E_{current}$ (0.54) was higher than $E_{0.5}$ and lower than E_{max} (0.89).

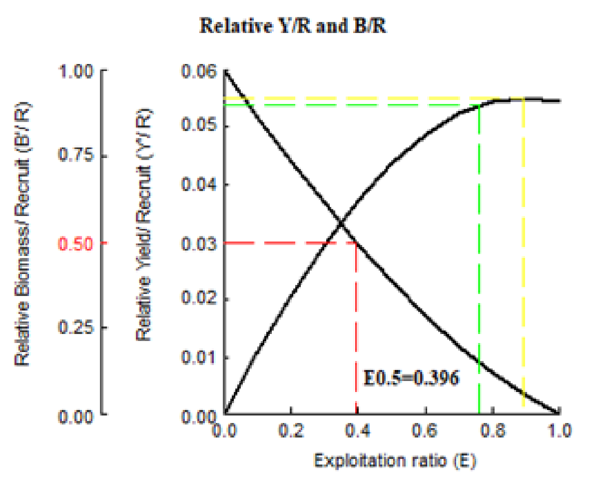

Figure 9: Yield per recruit and biomass per recruit of *P. pelagicus*.

DISCUSSION

Length based stock assessment data were used to determine the VBGF (CW_∞ and K). These values did not show much difference when compared by other authors. The current study results (CW_∞=18.27 cm and K=0.46 year^{-1}) were compared to previous studies from different areas (Table 2). 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 [6]. In the present study, the value of t_0 (-0.41y^{-1}) was higher than the value obtained from [6, 14, 33]. Indonesia t_0=-0.963; India t_0=-0.975 and Egypt=-0.998y^{-1}. The negative t_0 values indicate the crab species were fast grower during juvenile stage [7, 34].

For any fishery, the estimation of growth performance index is important for the stock assessment [18, 34]. In the present study, the growth performance was calculated at 2.19 and shows that the environmental conditions of the Gulf waters were suitable for the growth of the blue swimming crab. Growth performance values may be different because of the ecological and geological conditions as well as input values of growth parameters [35].

Table 2: Comparison of growth parameter (CW_∞ and K) with some of the previous studies in different locations.

Location	Sex	CW_∞ (cm)	K (y^{-1})	Source
Oman coastal water	Male	10.84	1.68	Mehanna et al., 2013 [13]
Coastal water, Persian Gulf	Male	19.1 18.5	1.7 1.6	Safiie et al., 2013 [36]
Kung Krabean Bay, Thailand	Male female	14.3 16.7	2.75 1.13	Kunsook et al., 2014 [37]
Pangkep, Indonesia	Male Female	17.4 18.6	1.2 1.5	Ihsan et al., 2014 [38]
Lasongko Bay, Indonesia	Male Female	15.2 17.3	0.93 0.68	Hamid and Wardiatno, 2015 [33]
Northern Arabian Sea, Pakistan	Combined	17.85	1.7	Afzaal et al., 2016 [14]
Mediterranean coast, Egypt	Combined	18.3	0.27	El-Far et al., 2018 [39]
Jakarta Bay, Indonesia	Combined	15.7	1.12	Panggabean et al., 2018 [40]
Kwandang waters, Indonesia	Male Female	17.4 18	1.11 1.24	Tirtadanu and Umi Chorijah, 2019 [41]
South Kalimantan, Indonesia	Combined	20.4	1.1	Suman et al., 2020 [42]
Red Sea, Egypt	Combined	21.19	0.41	El-Kashif et al., 2021 [6]
Present study	Combined	18.27	0.46	

For management purposes, age and length at first maturity is important because exploitation has to let some stocks, which are at the same or bigger size when they reach maturity, still live [43]. The length at first maturity L_m of female blue swimming crab was 10.92 cm was smaller than the results from Indonesia [33,44]. On the other hand, the current size at maturity was higher than those results estimated from different localities [40,45,46]. The spawning season of *P. pelagicus* extended from February to April and there are also some indications that there may be another breeding during the month of October. Nikolsky stated that L_m value is affected by some ecological factors, such as temperature, the depth and type of habitat, food availability and light [47]. The difference in L_m value for each fish is caused by the different size of samples collected, the maximum and minimum length, and frequency of fish that are gonad mature [48]. Further analysis showed that the carapace width at first capture 11.15 cm was higher than the length at maturity. This condition is not recommended in terms of fisheries management. It was recommended that L_m value was larger than L_c value. It was stated that the carapace width at first capture was 12.7 cm from Tanah Laut, Indonesia.

Table 3: Population parameters of the blue swimming crab from different areas.

Area	Sex	Mortality (year^{-1})			E (y^{-1})	Source
		Z	M	F		
Thailand	M F	8.15 6.95	2.07 1.53	4.53 4.88	0.56 0.7	Kunsook, 2011 [49]
Oman Coastal Waters	Combined	7.9	3.2	4.7	0.59	Mehanna et al., 2013 [13]
Pangkep Regency South Sulawesi	M F	2.53 3.22	1.44 1.27	1.09 1.95	0.43 0.6	Ihsan et al., 2014 [38]
Lasongko bay, Southeast Sulawesi	M F	2.8 2.95	1.09 0.86	1.71 2.09	0.61 0.71	Hamid and Wardiatno, 2015 [33]
Arabian Sea Pakistani Waters	Combined	4.6	1.68	2.92	0.63	Afzaal et al., 2016 [14]
Tanah Laut, Indonesia	Combined	3.04	1.24	1.8	0.59	Suman et al., 2020 [42]
Red Sea, Egypt	Combined	2.93	1.01	1.92	0.66	El-Kashif et al., 2021 [6]
Present study	Combined	1.53	0.7	0.83	0.54	

The total, natural and fishing mortality of blue swimming crab were estimated at 1.53, 0.70 and 0.83 year^{1}, respectively. Table 3 shows the variation of the mortality rates of *P. pelagicus* and shows the current value is closer or higher than that of the different areas. The differences in the value of mortality rates in several waters were caused by the different levels of effort number, predator, and environment condition [50]. The natural mortality coefficient M value in several waters appeared to be smaller than the F value, and this suggests that most of the blue swimming crab died due to capture. It was stated that, the overfishing occurred if the value of E is more than 0.5 and the stock will be endangered, thus the effort will decrease to sustain the stock. In the present study the exploitation rate estimated at 0.54 y^{1} [50].

The yield per recruit of *P. pelagicus* increased rapidly as fishing mortality increased and reach to maximum value (MYP/R=47.64 g) at the fishing mortality of F=6.0y^{-1}. At the present value of fishing mortality (F=0.83y^{-1}), age at first capture (Tc=1.64y^{-1}) and natural mortality (M=0.70y^{-1}), the current YPR was estimated to be 39.72 g, only 17.0% less than the maximum yield per recruit. By increasing the fishing morality to the maximum (F=6.0y^{-1}), the Y/R will increase to 47.64 g and the biomass per recruit B/R will decrease to 5.71 g.

CONCLUSION

In the present study, the growth parameters of *P. pelagicus* were studied and indicate females has shorter longevity and fast growth rate than males. The mortality parameters from this study indicate the highest fishing pressure was observed. The current fishing mortality rate (F=0.83y^{-1}) was by far in excess of the precautionary target (F_{opt}=0.35y^{1} and limit F_{limit}=0.47y^{-1}). The size at first maturity L_m of female blue swimming crab was 10.92 cm was than the size at first capture.

REFERENCES

1. Hosseini MV, Amir P, Yaghob M, Ali. Sex ratio, size distribution and seasonal abundance of blue swimming crab, *Portunus pelagicus* (Linnaeus, 1758) in Persian gulf coasts, Iran. WASJ. 2012; 17(7):919-925.
2. Smith GS, Sumpton WD. Sand crabs a valuable fishery in south east Queensland. Qld Fisherman. 1987;5:13-15.
3. Chande AI, YD Mgaya. The Fishery of *Portunus pelagicus* and species diversity of portunid crabs along the coast of Dar es Salaam, Tanzania. Western Ind Ocean J Marine Sci. 2003;2: 75-84.
4. Svane I, GE Hooper. Blue swimmer crab (*Portunus pelagicus*) fishery. Fishery assessment report to PIRSA for the blue swimmer crab fishery management committee. South Australian Research and Development Institute Aquatic Sciences. 2004.
5. Sara L, W Muskita, O Astuti, Safilu. Some population parameters of blue swimming crab (*Portunus pelagicus*) in Southeast Sulawesi waters, Indonesia. AACL Bioflux. 2017;10(3): 587-601.
6. El-Kasheif Midhat A, El-Far A M, El-Kasheif AM, Ibrahim SA, Flefel HE. Fishery biology and population structure of the blue swimmer crab, *Portunus pelagicus*, from the Red Sea, Egypt. Egyptian J Aqua Biol Fisheries. 2021;25(6):269-283.
7. Heath JR. The crabs of Dar es Salaam, Part I: Portunidae. Tanzania Notes Rec. 1973.
8. Bwathondi POJ, G Mwaya. The fishery of crustacea and mollusca in Tanzania. In: Iversen, S.A. & Myklevoll, S. (edn) The proceedings of the NORAD-Tanzania seminar to review the marine fish stocks and fisheries in Tanzania.1985.
9. Haefner Jr PA. The biology and exploitation of crabs. In: Provenzano Jr., AJ (edn) The biology of Crustacea: economic aspects, fisheries and culture. Academic Press Orlando. 1985;111-166.
10. Stephenson W. The evolution and ecology of portunid crabs, with special reference to Australian species, In the evolution of living organism. Melbourne, Australia. 1962;34-47.
11. Zainal KAY. Natural food and feeding of the commercial blue swimmer crab, *Portunus pelagicus* (Linnaeus, 1758) along the coastal waters of the Kingdom of Bahrain. J Association Arab Universities Basic Appl Sci. 2013; 13(1): 1-7.
12. FAO. The state of world fisheries and aquaculture 2020. Sustainability in action. Rome. 2020.
13. Mehanna SF, Khvorov S, Al-Sinawy M, Al-Nadabi Y, Al-Mosharafi M. Stock assessment of the blue swimmer crab *Portunus pelagicus* (Linnaeus, 1766) from the Oman coastal waters. Int J Fish Aquat Sci. 2013;2:1-8.
14. Afzaal ZM. Kalhoro M, Buzdar A, Nadeem F, Saeed A, Ahmed H. Stock assessment of blue swimming crab *Portunus pelagicus* (Linnaeus, 1758) from Pakistani waters (Northern Arabian Sea). Pakistan J Zool. 2016; 48(5):1531-1541.
15. Farrag E, Al-Zaabi A, Nuqui-Romina L. An analysis of experimental fishing traps in the coastal area of the United Arab Emirates. Int J Scien and Res Publications. 2020;10(10):468-474.
16. Gayanilo FP. Sparre P, Pauly D. FAO-ICLARM stock assessment tool (FiSAT II) User's Guide, FAO computerized information series (Fisheries). Rome, FAO. 2005;266.
17. Pauly D. Length-converted catch curves: A powerful tool for fisheries research in the tropics (part II). ICLARM Fishbyte. 1984;2:17-19.
18. Pauly D, J Munro. Once more on the comparison of growth in fish and invertebrates. Fish Byte. 1984;2:21-23.

19. Pauly D. Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper, Rome, Italy. 1983;52.

20. Beverton RJH. Patterns of reproductive strategy parameters in some marine teleost fishes. J Fish Biol. 1992;41 (B):137-160.

21. King M. 1995. Fisheries biology, assessment and management. Fishing News Book. 1995;341.

22. Snedecor GW, Cochran WG. Statistical methods. Oxford and IBH Publishing Co., New Delhi. 539.

23. Alverson DL, MJ Carney. A graphic review of the growth and decay of population cohorts. ICES J Mar Sci. 1975; 36:133-143.

24. Rikhter VA, VN Efanov. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res. Doc., 1976;76 (VI/8):12.

25. Hoenig JM. Empirical use of longevity data to estimate mortality rates. Fish Bull.1983; 82;898-902.

26. Pauly D, JF Caddy. A modification of Bhattacharya's method for the analysis of mixtures of normal distribution. FAO fisheries Circular. 1985;781:1-16.

27. Patterson K. Fisheries for small pelagic species: An empirical approach to *Portunus pelagicus* (Linnaeus) with a note on the zcea of Thalamita crenata Latreille. J Bomb Nat Hist Soc. 1992;51: 674-89.

28. Beverton RJH, SJ Holt. On the dynamics of exploited fish populations. UK Ministry Agriculture and Fish, Fisheries. 1957;19, 533.

29. Sparre P, Venema SC. Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper. 1992;376.

30. Beverton RJH, SJ Holt 1966. On the dynamics of exploited fish populations. Fisheries Investigation Series. 1996;2.

31. Pauly D, ML Soriano. Some practical extensions to Beverton and Holt's relative yield-per-recruit model. First Asian Fisheries Forum, Asian Fisheries Society (edn) Manila, Philippines. 1986. 149-495.

32. Gayanilo FC, D Pauly. The FAO ICLARM stock assessment tools (FISAT) reference manual. FAO computeter information sereies (Fisheries). 1997;8:262.

33. Hamid A, Y Wardiatno. Population dynamics of the blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) in Lasongko Bay, Central Buton, and Indonesia. AACL Bioflux. 2015; 8: 729-739.

34. Sparre P, SC Venema. Introduction to the tropical fish stock assessment. Manual. FAO Fisheries Technical Report. 1998;407.

35. Devaraj M. Age and growth of the three species of seerfishes Scombermorus commerson, S. guttatus, S.lineolatus. Indian J Fish. 1981;28:104-127.

36. Safaie M, J Pazooki, B Kiabi, MR Shokri. Reproductive biology of blue swimming crab, *Portunus* segnis (Forskal, 1775) in coastal waters of Persian Gulf and Oman Sea, Iran. Iranian J Fish Sci. 2013;12(2):430-44.

37. Kunsook CN, Gajaseni N, Paphavasit N. A stock assessment of the blue swimming crab *Portunus pelagicus* (Linnaeus, 1758) for sustainable management in Kung Krabaen Bay, Gulf of Thailand. Trop Life Sci Res. 2014;25(1):41-59.

38. Ihsan, Wiyono S, Wisudo S, Haluan J. A study of biological potential and sustainability of swimming crab population in the waters of Pangkep Regency South Sulawesi Province. International Journal of Sciences: Basic Appl Res. 2014;16:351-363.

39. El-Far A, M El-Kasheif, M Habashy. Fisheries biology of blue swimmer crab, *Portunus Pelagicus*, in the Mediterranean water front Egypt. Fish Forum Proc. Rome, Italy. 2018;222.

40. Panggabean AS, ARP Pane, A Hasanah. Population dynamic and exploitation rate of blue swimming crab (*Portunus Pelagicus* Linnaeus, 1758) in Jakarta Bay waters. J Lit Perikan Ind. 2018; 24(1):73-85.

41. Tirtadanu, Umi Chodrijah. Fishery, population parameters and exploitation status of blue swimming crab (*Portunus pelagicus*) in Kwandang Waters, Indonesia. AACL Bioflux. 2019;12(4):1323-1334.

42. Suman A, Pane AR, Lestari P. Stock status of blue swimming crab (*Portunus pelagicus*) in Tanah Laut, South Kalimantan, and its adjacent waters. Indonesian Fisheries Research Journal. 2020;26(1):51-60.

43. Sudjastani T. Population dynamic of scad in Java sea. Laporan Penelitian Perikanan Laut. 1974;1:30-64.

44. Ningrum VP, Ghofar A, Ain C. Some biological aspects of fisheries of blue swimming crab (*Portunus pelagicus*) in Betahwalang and surrounding waters. Indonesian J Fisheries Scie Technol. 2015;11(1):62-71.

45. Abdel Razek F, Farghaly M, Sorour J, Attia A. Population characteristics, maturation and spawning of the blue swimmer crab *Portunus pelagicus* in Eastern Mediterranean Sea, Egypt. Asian J Biolog Sci 2019;12:626-636.

46. Sabrah MM, El-Refaii A, Ali TG. Reproductive characteristics of the blue swimming crab, *Portunus pelagicus* (Decapoda, Brachyura: Portunidae) from the Bitter Lakes, Suez Canal, Egypt. African J. Biol. Sci. 2020;16(1):79-91.

47. Nikolsky CV. The Ecology of Fishes. Academic Press: London and New York

48. Sivakami S, Raje SG, Feroz Khan M, Kizhakudan SJ, Vivekanandan E, Rajkumar U. Fishery and biology of Priacanthus hamrur (Forsskal) along the Indian coast. Indian J Fish. 2001;48(3):277-289.

49. Kunsook C. Assessment of stock and movement pattern for sustainable management of blue swimming crab *Portunus pelagicus* (Linnaeus, 1758): Case study in Kung Krabaen Bay, Chanthaburi Province, Thailand (Doctoral dissertation, Chulalongkorn University).

50. Pauly D, Ingles J, Neal R. Application to shrimp stocks of objective meathods for the estimation of growth, mortality and recruitment-related parameters from length-frequency data (ELEFAN I and II). Fishing News Books Ltd.