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Stock Assessment of the Blue Swimmer Crab *Portunus pelagicus* (Linnaeus, 1766) from the Oman Coastal Waters

Sahar F. Mehanna, Sergey Khvorov, Mansoor Al-Sinawy, Yehia S. Al-Nadabi and Mohamed N. Al-Mosharafi
Marine Science and Fisheries Centre, P.O. Box, 427, Muscat, Oman

Abstract: The stock assessment of the blue swimmer crab, *Portunus pelagicus* was made based on monthly length frequency data collected from four landing sites along the Oman coasts on both Arabian and Oman Seas from January, 2011 to May, 2012. Age and growth have been estimated from the length-frequency distribution of up to 1000 specimens. Age composition was determined using Bhattacharya's method and the results showed that the maximum life span of *P. pelagicus* was about 15 months. Bertalanffy (1938) growth parameters didn't differ significantly between sexes and the obtained values of K were K = 1.85, 1.68 and 1.68 y^{-1} and CL_∞ values were 102.83, 109.57 and 108.46 mm for male, female and sexes combined, respectively. The values of total mortality coefficient (Z), natural mortality coefficient (M) and fishing mortality coefficient (F) were 7.85, 3.15 and 4.7 y^{-1}. The yield per recruit and SSB analysis showed that 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 (83% of its current value) will accompanied with a negligible increase in Y/R (2.7%) and a considerable decrease in both biomass per recruit (21.1%) and spawning stock biomass (37.6%).

Keywords: Arabian sea, Oman sea, population dynamics, portunidae, *Portunus pelagicus*, rational exploitation, stock assessment

INTRODUCTION

Crustaceans, such as penaeid shrimp, crabs and lobsters have recently become very important due to the high demand for them in world markets. Marine crabs are one of the valuable seafood items of great demand both in the domestic markets and the export industry of Oman. In the past, the Omani people didn't accept crabs as a food and this fishery was totally ignored, but now the crab demand and consumption by Omani and other nationalities that live and work in Oman has increased.

A survey in the Mutrah fish market and five hypermarkets as well as the Oman fish company indicated that, the crab market in Muscat city achieves at least 200,000 OR (OR ≈ 2.6 $) per year (the crab consumed by hotels, restaurants and other fish markets in Muscat not included). This survey was for one species of edible crabs in Oman; *Portunus pelagicus*. These preliminary statistics of the net profit achieved from crabs' trading in one city, if this trading is managed well, it will lead to opening new markets and create jobs as well as will be a source of hard currency from exporting crabs, whether fresh or processed (Khvorov and Mehanna, personal observation).

Although Sultanate of Oman has a good fishery for marine crabs (at least 150 species of which 14 are edible), there are no any records about their catches in the fishery statistics records. However, the crabs are in demand in Oman markets, which indicates the potential of this market (it could be generate multi-million dollars revenue annually), so there are prerequisites for the development of this fisheries based on stock assessment studies.

The blue swimmer crab *Portunus pelagicus* (known as flower crabs, blue crabs, blue swimmer crabs, blue manna crabs or sand crabs) is the most commercially important marine species in Oman coastal waters. It is a large crab found in nearshore marine and estuarine waters throughout the Indo-West Pacific (Stephenson, 1962; Kailola *et al*., 1993), Red Sea and Suez Canal (Mehanna, 2005) and the Middle-Eastern coast of the Mediterranean Sea (Mehanna and Haggag, 2007; Mehanna and El-Aiatt, 2011). This species 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 (Williams, 1982; Edgar, 1990).

For rational exploitation of the crab resources in Oman, understanding the present status of the stocks should be done. This study is the first investigation of the status of the blue swimmer crab stock off the Oman Sea coast.

MATERIALS AND METHODS

Between January 2011 and May 2012, 998 crabs (584 males and 414 females with carapace length range of 27 to 92 mm and of 39 to 96 mm, respectively) were

Corresponding Author: Sahar F. Mehanna, Marine Science and Fisheries Centre, P.O. Box, 427, Muscat, Oman

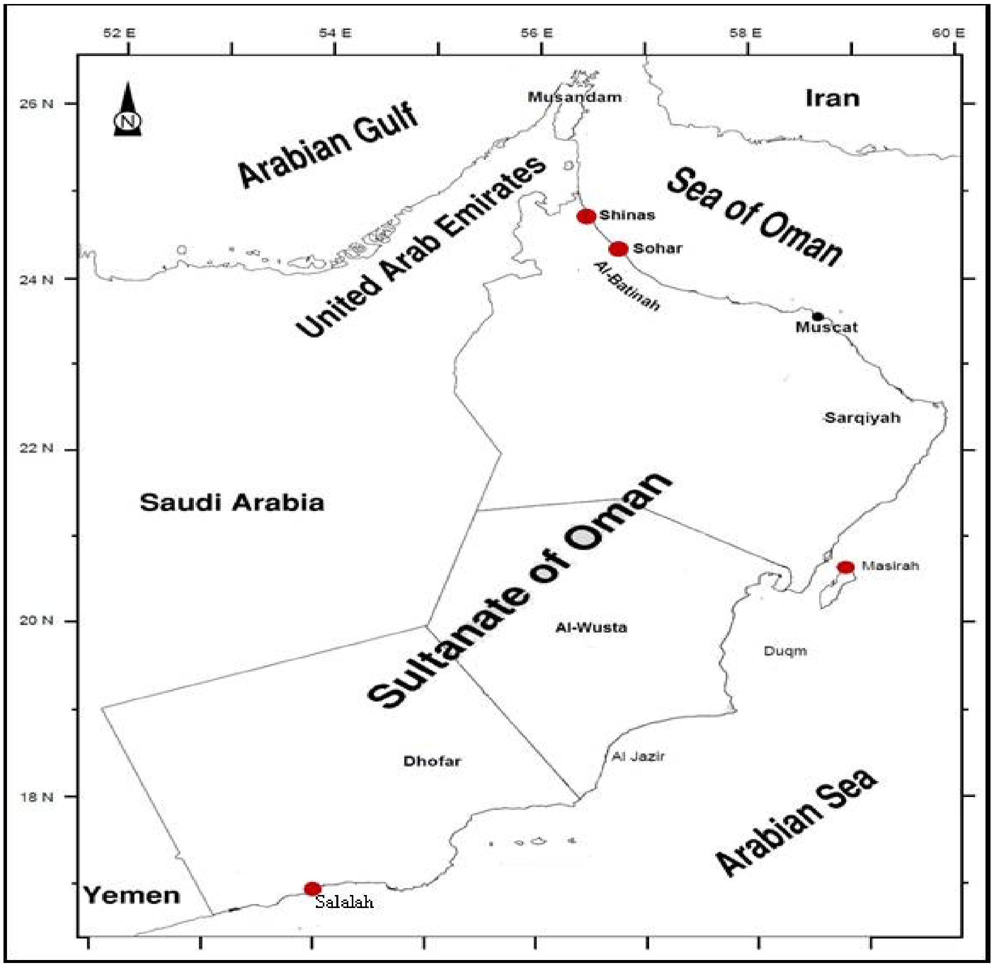

Fig. 1: Map of Oman showing the sampling sites

collected from four fishing grounds; 2 on the Sea of Oman (Shinas and Sohar) and 3 on the Arabian Sea (Masira Island and Salalah) (Fig. 1). All samples were gathered by a team from gear technology lab as a part of crustacean project (The efficiency of traps for catching crabs) using six types of traps, Oman style (2 types), Japanese style and Chineese (3 types). The monthly length frequencies were grouped in 5 mm length classes for Modal Progression Analysis (MPA). Sexes were separated and their Carapace Length (CL) and Width (CW) to the nearest mm and their Body Weight (BW) to the nearest 0.1 g, were recorded for each specimen.

Longevity, growth parameters of the Bertalanffy (1938) growth model (L_∞ and K), total mortality coefficient (Z), natural mortality coefficient (M), length at first capture (L_c), relative yield per recruit and relative biomass per recruit and Thompson and Bell analysis were estimated by applying the FAO-ICLARM Fish Stock Assessment Tools (FiSAT II) and the following methods were used:

- The Bhattacharya (1967) method to identify modes in the length frequency data. For each sex, the length frequency samples were resolved and the results were then used as input to Ford (1933) and Walford (1946) plot to estimate the growth parameters ($L\infty$ and K)
- Semi logarithmic regression method of Ricker (1975) and Beverton and Holt (1956) equation to estimate Z
- Alverson and Carney ($M = 3*K/ [exp (t_{max}*0.38*K) - 1]$) and Rikhter and Efanov (1976) ($M = (1.521/t_{mass})^{0.72} - 0.155$) formulae to estimate M, where t_{max} is the age of the oldest fish and t_{mass} is the age of massive maturation
- Length converted catch curve and probability of capture (Pauly, 1984) to estimate the length at first capture L_c
- Yield per Recruit (Y/R), Biomass per Recruit (B/R) and Spawning Stock Biomass (SSB) and was estimated using the VIT program (Lleonart and Salat, 1997). All these calculations were done for sexes combined as any management measures were planned for sexes combined
- The relation between CL and BW was computed using the formula $BW = a\ CL^b$, where BW was the

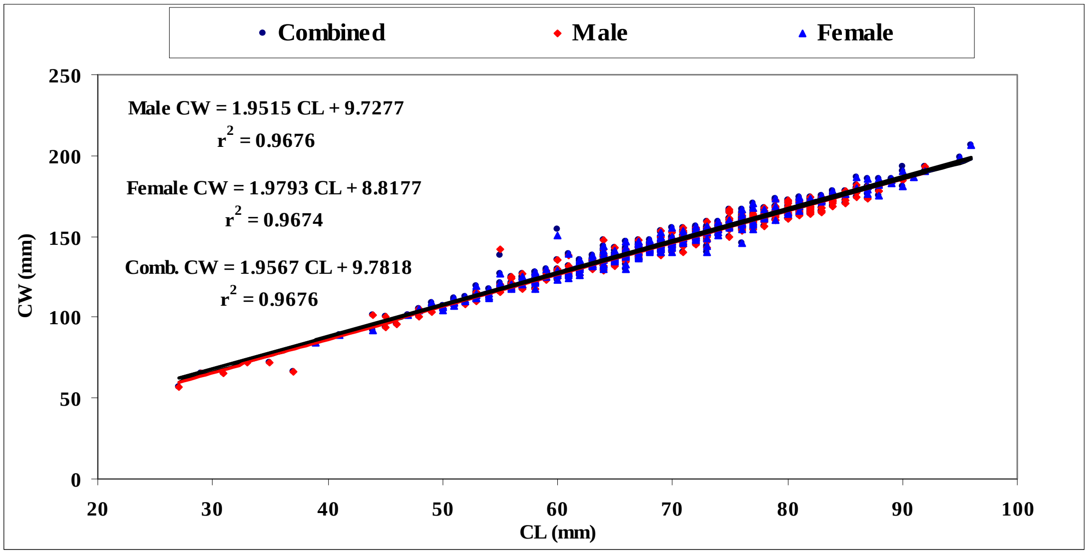

Fig. 2: Carapace length-width relationship of *Portunus pelagicus* from Oman

Body weight, CL was the carapace length and a and b were constants

- The relation between the CL and CW was estimated using the following equation:

CW = a + b CL

where a and b are the constants of the relationship.

RESULTS AND DISCUSSION

The purpose of fish stock assessment is to provide estimates of the state of the natural stock. The state of the stock is defined by its abundance at a specific time, together with the mortality and growth that control its development. These estimates consequently were used to fisheries management advice for reviewing different fishing options (Lassen and Medley, 2001).

Crabs are considered recently one of the most valuable fishery resources in Oman coastal waters and understanding their biology, dynamics and their interaction with the other fish communities inhabiting the area will help in proposing a plan for sustainable development of this fishery in Oman. As the stock assessment of blue swimmer crab has been never done in Oman coastal waters, the present study is the first to provide the biological and dynamical parameters required for rational exploitation of *P. pelagicus* stock in Oman.

Carapace length-width relationship: The CL of *P. pelagicus* was plotted against the CW to estimate the CL-CW relationship. The CL varied from 27 to 92 mm for males and from 39 to 96 mm for females while the CW varied from 57 to 193 mm for males and from 84 to 206 mm for females. The obtained equations (Fig. 2) were:

Males	:	CW = 9.7277 + 1.9515 CL (r^2 = 0.968)
Females	:	CW = 8.8177 + 1.9793 CL (r^2 = 0.967)
Combined sexes	:	CW = 9.7818 + 1.9567 CL (r^2 = 0.968)

Carapace length-body weight relationship: The body weights BW of *P. pelagicus* were varied from 10 to 675 g for males and from 36 to 730 g for females for CL range of 27-92 mm for males and 39-96 mm for females. The obtained CL-BW equations (Fig. 3) were:

Males	:	W = 0.0003 CL $^{3.1771}$ (r^2 = 0.968)
Females	:	W = 0.0012 CL $^{2.8675}$ (r^2 = 0.925)
Combined sexes	:	W = 0.0004 CL $^{3.111}$ (r^2 = 0.947)

An isometric growth was observed for both males and females CL-BW relationship where the exponent b not significantly different from 3 (95% confidence interval CI = 3.12-3.23 for male and 2.77-2.96 for female).

Carapace width-body weight relationship: The CW of *P. pelagicus* was varied between 57 and 193 mm for males and between 84 and 206 mm for females with BW of 10 to 675 g for males and 36 to 730 g for females. The obtained CW-BW equations (Fig. 4) were:

Males	:	W = 0.00002 CW $^{3.2401}$ (r^2 = 0.950)

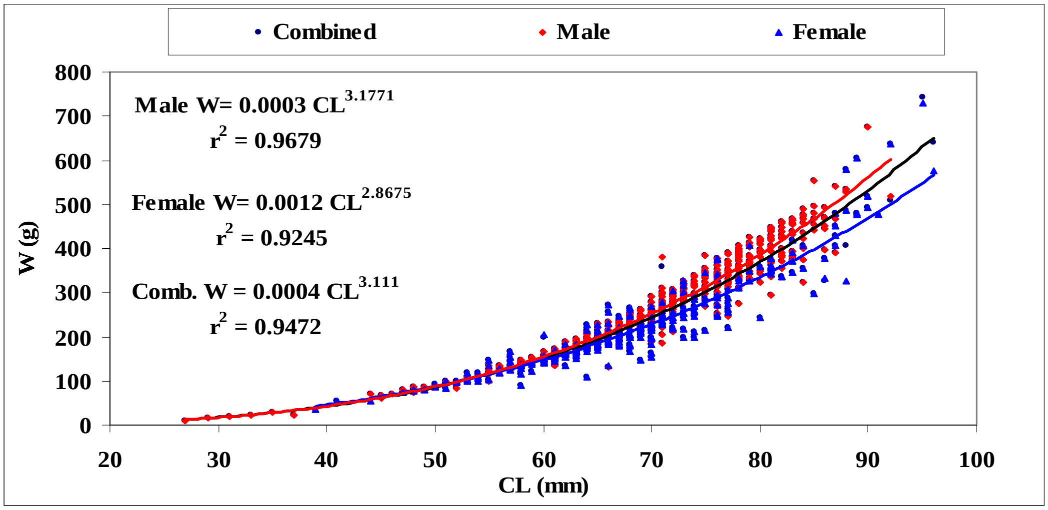

Fig. 3: Carapace length-body weight relationship of *Portunus pelagicus* from Oman

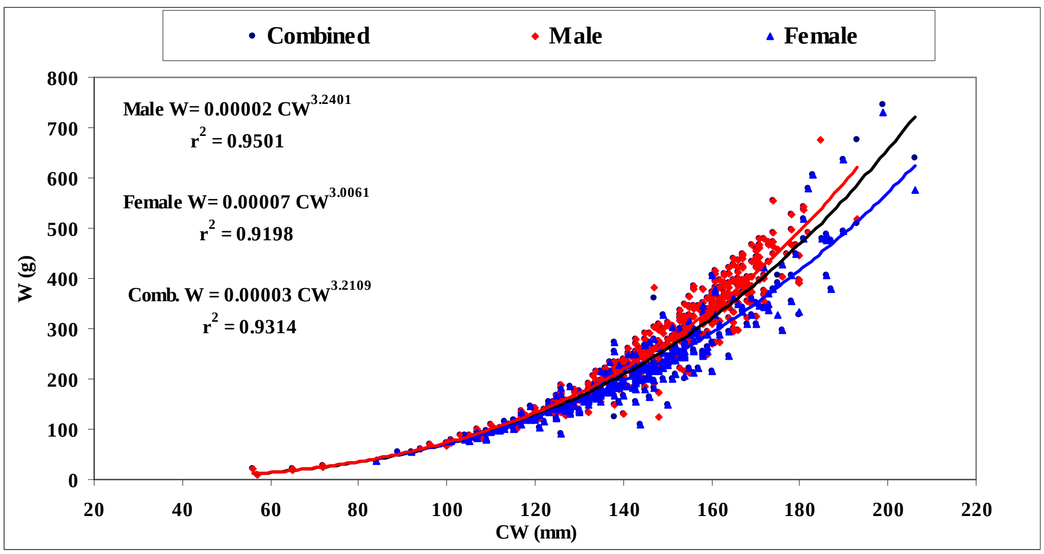

Fig. 4: Carapace width-body weight relationship of *Portunus pelagicus* from Oman

Females : $W = 0.00007\ CW^{3.0061}$ ($r^2 = 0.920$)

Combined sexes : $W = 0.00003\ CW^{3.2109}$ ($r^2 = 0.931$)

It is obvious that the CW of males was grown allometrically as the body weight increase (95% confidence interval CI = 3.23-3.36), while that of females has an isometric growth (95% confidence interval CI = 2.91-3.11)

Sex ratio and size structure: Males of *P. pelagicus* were outnumbered females in all sampling months, with an overall male-to-female ratio 1:0.71. The sex ratio was significantly different from the ideal ratio 1:1 ($p>0.05$). Male size range was 27-92 mm CL with a mean of 71.26±10.14 while that of female was 39-96 mm CL with mean of 67.58±9.93. Males are characterized by a higher mean length as the majority of samples were in length range of 70 to 85 mm CL, while that of females in length range of 60-75 mm CL (Fig. 5). Also, the smallest specimens in the samples were males while the largest ones were females.

Age and growth: Age determination and consequently the estimation of growth of crabs are associated with many difficulties because direct methods cannot be applied for this purpose. However, age can be determined indirectly by standard statistical methods that allow conversion of length frequency data into age groups. For the blue swimmer crab in Oman Sea, the longevity was about 15 months for males and females

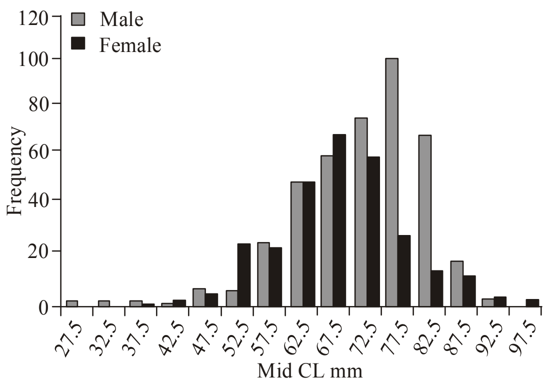

Fig. 5: Size distribution for male and female *Portunus pelagicus* from Oman

using Bhattacharya method. These results are in agreement with the previous studies; in South Australia, *P. pelagicus* reaches a size of 150 mm CW (base of spines) in about 18 months (Smith, 1982). In south-west Australia, a size of 159 mm CW is reached in about 18 months (De Lestang *et al*., 2000, 2003), while in the Peel-Harvey Estuary, a size of 127 mm CW (tips of spines) is reached in about one year (Potter and de-Lestang, 2000). In south-west India, a size of 132.5 mm CW is reached by females in one year (Sukumaran and Neelakandan, 1997). For the blue swimmer crab at Bitter Lakes, the longevity was about one year for maximum CL of 88 mm (172 mm CW) (Mehanna, 2005) and in Port Said waters was 2 years for maximum CL of 91 mm (173 mm CW) (Mehanna and Haggag, 2007), while in Bardawil lagoon the longevity was one year for maximum CL of 69 mm (138 mm CW) (Mehanna and Al-Aiatt, 2011).

The Bhattacharya method was also used to analyze the monthly length frequency data to obtain the modal length values. By resorting to the mean of modal lengths, progression from 14 mm CL up to the CL_{max} could be traced in 15 months. The maximum growth rate in CL was recorded during the first 3 months of life, while the body weight reached its maximum growth rate at age of 12 months for males and 9 months for females (Table 1). This agrees with the findings of Smith (1982), Kangas (2000), Kumar *et al.* (2000, 2003), Sumpton *et al.* (2003), De Lestang *et al.* (2003), Svane and Hooper (2004), Mehanna (2005) and Mehanna and Al-Aiatt (2011).

Growth parameters: The values of estimated growth parameters (K and $L\infty$) of *P. pelagicus* from Oman Sea indicate the short longevity and fast growth rate of this species. Applying Ford-Walford plot to the mean lengths obtained from MPA, the values of K and $L\infty$ for males, females and combined sexes were 1.85, 1.68 and 1.68 y^{-1} and 102.83, 109.57 and 108.46 mm respectively. Similar results were obtained by other authors (Table 2).

Mortality rates: Total mortality coefficient (Z) estimated from the semi logarithmic regression method (Ricker, 1975) was 8.07 y^{-1}, while the Beverton and

Table 1: Mean lengths obtained from bhattacharya method and calculated weights of *Portunus pelagicus* in Oman coastal waters

	Mean carapace length (mm)			Calculated weights (g)		
Age (year)	♂♂	♀♀	♂+♀	♂♂	♀♀	♂+♀
0.25	33.11	34.74	34.21	20.24	31.44	23.70
0.50	57.42	58.11	57.95	116.37	137.46	122.16
0.75	75.93	78.86	77.26	282.74	329.93	298.87
1.00	88.22	91.80	90.69	455.39	510.07	492.07
1.25	91.05	94.81	93.91	503.44	559.51	548.49

Table 2: The estimated values of K and L_{∞} of *Portunus pelagicus* (*CW)

		K/year			CL_{∞} cm		
Author and locality	Method	♂♂	♀♀	♂+♀	♂♂	♀♀	♂+♀
Australia:							
Sumpton *et al.* (1994)	Length frequency analysis	1.60	1.61	-	17.50*	17.00*	-
Sumpton *et al.* (2003)	Modal progression analysis	1.62	1.61	-	17.70*	17.20*	-
India:							
Sukumaran and Neelakandan (1997)	Length frequency analysis	1.14	0.97	-	21.10*	20.40*	-
Josileen and Menon (2004)	Gulland and Holt	1.82	1.70		21.98	21.18	
	Munro	1.90	1.64		20.80	21.10	
	Fabens	1.80	1.62		20.41	18.86	
Egypt:							
Mehanna (2005)	Bhattacharya (Gulland and Holt plot)	1.73	1.61	1.67	10.40	9.80	10.50
(Bitter lake)	Wetherall (von Bertalanffy plot)	1.78	1.70	1.63	10.30	9.70	10.20
	Elefan I	1.66	1.59	1.62	10.20	9.60	10.20
Mehanna and Haggag (2007)	Bhattacharya (Chapman plot)	1.59	1.48	1.40	10.21	10.45	10.67
(Mediterranean sea)	Wetherall (von Bertalanffy plot)	1.48	1.39	1.33	10.35	10.39	10.53
	Elefan I	1.66	1.56	1.52	10.15	10.33	10.72
Mehanna and Al-Aiatt (2011)	Integrated method			2.28			7.91
(Bardawil lagoon)	Powell-Wetherall			2.04			8.38
Oman sea (present study)	Bhattacharya (Ford and Walford plot)	1.85	1.68	1.68	10.28	10.96	10.84

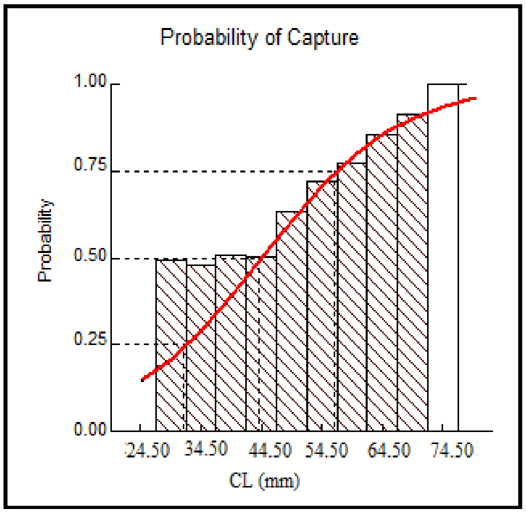

Fig. 6: Carapace length at first capture of *Portunus pelagicus* from Oman

Holt (1956) equation gave Z estimate of 7.72 y^{-1}. According to the M/K ratio given by Beverton and Holt (1959), the natural Mortality coefficient (M) lies between 2.53 and 4.21. Rikhter and Efanov (1976) formula gave an estimate of M at 2.34 y^{-1}, while Alverson and Carney equation gave M value of 3.14 y^{-1}. Using a mean values for Z and M, the respective value of Fishing mortality coefficient (F) was 4.7 y^{-1}.

Length at first capture (L_c): The length at first capture (the length at which 50% of the crabs are vulnerable to capture) was estimated as a component of the length converted catch curve analysis (Fig. 6). The values of L_c obtained was 44 mm which corresponding to an age of 4 to 5 months. It was noticed that the smallest specimen in the catch was of 27 mm CL and the smallest mature specimen was of 45 mm CL, while the L_m (Length at first sexual maturity) was between 60-65 mm CL (6-7 months). This means that there is a need to establish a minimum size limit ($\geq L_m$) and a full protection of both young individuals and berried females.

Yield per Recruit (Y/R) and SSB analysis: The Y/R, B/R and SSB analysis (Fig. 7) showed that at the present level of F (Factor 1), a Y/R of 47.25 g can be achieved and increasing the fishing mortality would give a higher Y/R reaching its maximum (48.53 g) at F-factor of 1.83. However, the increase in fishing mortality by about 83% would be associated with a negligible increase in Y/R of the order of 2.7%. At the same time the biomass per recruit B/R will decrease by about 21.1% and the SSB also will decrease by about 37.6%. This result is in agreement with the finding of Garcia (1985) who pointed out that because of the values characteristic of short lived crustacean (high natural mortality M and high growth rate K), the Yield per Recruit (Y/R) increases exponentially towards a quassi asymptote with increasing fishing mortality and the maximum yield per recruit is reached only at an unreasonably high level of fishing mortality.

CONCLUSION

According to the results of Y/R analysis, it could be concluded that there is a potential to increase the *P. pelagicus* catch in Oman Sea but this will need some management regulations. It is imperative to restrict the level of effort at its present level which would prevent overexploitation of the crab stock in the Oman Sea. Replace nets by traps with appropriate holes in all fishing grounds along the Oman coasts to conserve the

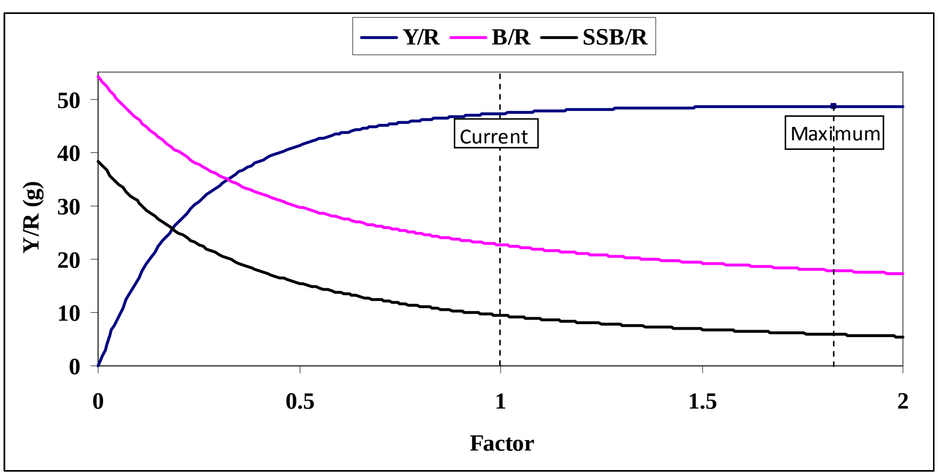

Fig. 7: Yield per recruit, biomass per recruit and SSB analysis of *Portunus pelagicus* in Oman

reproducible part of the population. Also, management controls include restrictions on the characteristics of fishing boats and the full protection of berried females. There is a need to study the crab movement patterns and perform egg per recruit analysis, as well as to study the trophic levels in the Oman coastal waters and the interaction between the habitat and different species and among the different species themselves to ensure populations sustainability. Besides, it is important to improve the national statistics records on catch and fishing effort and to raise the awareness of fishermen about the fisheries management regulations.

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